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FURTHER STUDIES OF THE BIOLOGY OF THE MIGRATORY LOCUST (*PACHYTYLUS MIGRATORIOIDES* REICHE AND FAIRM), LOCUSTIDAE ORTHOPTERA

By SALUSTIANO S. GONZALES

Of the Bureau of Plant Industry

SEVEN PLATES

Various degrees of locust infestation have occurred in the Islands. In 1916, the infestation in the Islands comprised 114 towns in 35 provinces. In 1917, however, a marked improvement in the locust situation was observed and in the absence of reports on the appearances of locusts in cultivated areas the Islands were declared free from the pest. The following year, however, locusts in great numbers, appeared in Bukidnon, Cotabato, Davao, Sorsogon, Nueva Ecija, and Pangasinan. From this year, infested places increased up to the year 1922, when the maximum number of infested towns reached 440. Then, there followed a gradual decline of infestation until the year 1928 when the maximum number of infested towns was 164 in thirteen provinces. At the end of that year, only nine municipalities in five provinces remained infested. But on September 12, 1929, Tawit in the Mountain Province,—the only place reported infested—was freed. It is not, however, possible at present to declare the Islands free from the pest for only a comparatively small portion of the vast isolated places of the country has been explored by our locust inspectors, so that there is still the danger of locusts breeding in various unexplored regions of the Archipelago. It is, however, gratifying to note that at least for this short lapse of time, this much dreaded pest has been kept out of the cultivated areas.

Locusts are widely distributed throughout the world, but the Philippine migratory species is somewhat limited in its distribution. Pratt (1915) reported the genus *Pachytylus* from the Federated Malay States but the exact species is yet a moot question, while Uvarov (1921–22) reported this species *Locusta* (*Pachytylus*) *migratoria* as being confined (in Russia) to the basins of the Caspian and Aral Seas and of Lake Balkash. A more recent book by the same author (Uvarov, 1928) seems to point out that this insect, which he considers a tropical phase of *Locusta migratoria*, L., is more or less confined to the Tropics, especially in Africa, Madagascar, Federated Malay States, Formosa, Philippines, Borneo, and Australia. There are also reports of destructive locusts in Argentina (Gueffreire, 1911) but no mention is made of the species in question.

LIFE HISTORY OF THE MIGRATORY LOCUST

It was deemed necessary to make further observations on the life history and habits of the migratory locust since a more adequate knowledge of these is fundamental in the study of control measures.

This work was started in December, 1928. Experiments and observations were conducted both in the Insect Pests Laboratory at Alabang, Rizal, and in the fields of the several provinces infested with the pest during the time of the present study.

The original stock of specimens used in the present work was eggs obtained from Nueva Ecija Province on June 17, 1928. These eggs hatched on June 27 of the same year, and the nymphs taken to the Alabang Insect Pests Laboratory where studies and observations started. The first dates of laying were not recorded but the nymphs that hatched from these were at once confined singly in battery jars with soil, and grass and rice seedlings were introduced from time to time as feed. The dates of hatching as well as the dates of subsequent moltings were carefully recorded and descriptions of the different nymphal instars made.

Emergence and copulation.—Every adult female emerging from these hoppers was isolated in a battery jar with soil and a male from the same stock confined with her. The dates of the first and subsequent copulations as well as those of the first and subsequent layings were recorded. Of course, any copulations that took place during the night could not be detected, so that what are given here represent either the correct or minimum numbers of copulations that took place during the life of the female locusts. Every female that laid was transferred to

another jar to prevent confusion in labeling the different egg-masses. It was found that from the emergence of the female, copulation took place in from 22 to 34 days, with an average of 25.29 days (Table 1). As was generally observed, males came to sexual maturity at a much earlier date than did the females. This was evidenced by the males mounting other males or females before any of the latter from the same egg mass showed the same sign. In fact, numerous cases were observed where females struggled hard to free themselves from their male burdens. Several of these females could not successfully overthrow the males, in which cases, they just let the latter stay on their backs, but not one was observed to effect mating. These were but external manifestations of the differences in sexual maturities between males and females. Copulations occurred any time of the day and in almost any place. But usually a pair may be seen on the ground and unless disturbed they remain stationary except when the female moves about in search of food; for the female may eat while in copula. Some couples may also be found on top of grasses or bushes. At irregular intervals, during copulation, the male executes some sort of a jerking motion slightly loosening its hold on the female and swerving its body from one side of its mate to the other. These motions are interpreted as mere expressions of sexual excitement (Uvarov, 1928).

Copulations as observed in the laboratory lasted for from 50 to 110 minutes.

The locusts copulate more than once during their lifetime. Table 1 shows the number of copulations to range between 3 and 9, with an average of 5.78. The period between two successive matings was not uniform. While in some cases only one day intervened between two successive matings, in others this period was as long as 18 days.

Oviposition and fecundity.—The female locust lays more than once during her lifetime. This finding differs from that of Jones and Mackie (1913). According to these authors a female locust lays all her eggs at one time and that she dies shortly afterwards. As will be noted later, the female locust survived her period of fecundity by a number of days. The time elapsing from the first mating to the first laying ranged from 7 days to 13 days with an average of 9.19 days (Table 1). Although the female was found to copulate more than once during her lifetime, it was not noted that every mating was followed by laying. There were cases in which as many as five matings took

place before the next laying followed. On the other hand, there were instances in which only one mating took place before laying. No particular place nor time of the day was selected by the locusts for oviposition. The necessity of depositing the eggs forced the female insect to oviposit wherever she might be at the time. A case observed in Cabiao, Nueva Ecija, in which a swarm of locusts alighted in a region the ground of which was entirely covered with water. The females due to oviposit were forced to lay their eggs on the blades of tall grasses or on the leaves of trees above the water. Some of the eggs thus laid were collected and hatched in the laboratory. The laying of eggs above the ground was also noted in a number of cases in our cages in Alabang. The same case was noted by Riley (1891) and Walton (1916) in the case of the Rocky Mountain Locust, *Melanoplus spretus* and other American species; and in fact, grasshoppers, in general, lay their eggs in exposed places when the conditions of the ground are not favorable for oviposition.

Under normal conditions, however, the locust lays her eggs in the ground, in a hole about 6 centimeters deep. A good description of the manner in which the eggs were laid was made possible by placing a circular piece of cardboard on the surface of the soil in the central portion of the battery jars, leaving an exposed ring of the soil about 1½ centimeters in width. The soil used was a mixture of a clay dust and fine sand. This forced the locusts to oviposit close to the side of the jar so that every step of the process was seen through the glass. It was also found necessary to place at least 8 centimeters of soil in the jars, as the abdomen of the locust was extended to a length of about 6 centimeters while it was laying and when the tip of its abdomen reached the bottom of the jar or touched something hard, before the required depth of the hole was reached, the insect immediately withdrew its abdomen and abandoned the hole. It then searched farther for a more suitable portion to bore another hole in. Under these circumstances, a female may bore as many as fifteen holes before a suitable site is located. This is one explanation for the presence of numerous holes in egg infested field; but almost always, most of these deep holes which are easily discovered in an egg-infested area, do not indicate that eggs had been laid therein, for as will be seen later, locusts have the habit of covering the holes at the completion of oviposition.

Observations in the laboratory showed that in making the hole, the valves of the ovipositor were the ones principally used.

The closing and opening of these valves accompanied by the simultaneous pressing down of the abdomen into the soil, bored the hole. At first the valves were closed or brought together to form a firm point. The insect then pressed this down into the soil and simultaneously opened the valves or brought them apart. This pressed the particles of soil apart and a hole was created. Without withdrawing the tip of the abdomen from the bore thus made, the locust closed the valves once more. Once closed the insect turned the tip of her abdomen on its long axis so that the dorsal valves of the ovipositor were brought either to her right side and the ventral valves to the left, or vice versa, and again these were parted. Sometimes these valves were turned completely around, the dorsal valves being brought toward the ventral surface of the abdomen and the ventral valves toward the dorsal. When they were brought together once more, the abdomen assumed its former and normal position, that is, the dorsal valves were located dorsally and ventral valves ventrally. The abdomen was then partly withdrawn from the hole only to be inserted again, this time with greater pressure so that the valves of the ovipositor were pressed farther downward. Thus the opening and closing of the valves were repeated together with the turning of the abdomen along its axis and the greater pressure exerted by the insect each time a complete turn of the abdomen was made, until the hole reached the required depth. It must be noted that no particles of the soil were raised to the surface during the process; they were simply pressed apart by the abdominal walls, so that the sides of the hole thus made were smooth and even. The abdomen was extended to a length of about five or six centimeters to obtain the required depth of the hole. The abdominal segments were fully extended so that the whole abdomen assumed the form of a solid tube. In fact, it was so distended that the eggs could be detected from the outside through the body-wall, which had become semitrasparent. Much time was spent in putting the bottom of the hole into shape preparatory to egg-laying. From 23 to 27 minutes, with an average of 25 minutes were spent in boring the hole (Table 2) which was made almost perpendicular to the surface of the ground, the bottom a little more toward the posterior of the female.

When the hole was deep enough the locust rested a while before she began to lay her eggs. This period of rest consumed from 3 to 8 minutes with an average of 5.23 minutes (Table 2). Then by continuous convulsive movements of the abdomen, a

white bubbly, sticky substance was first laid thickly at the bottom of the hole. This substance turned brown when dry and assumed the consistency of a sponge. A slower convulsive movement followed which forced the eggs out one by one. These were lodged in the material that filled the bottom of the hole. Each egg laid was followed by a quantity of the spongy material. This seemed to protect the eggs from unfavorable climatic conditions and natural enemies. It served also to glue the eggs together. It was more thickly applied at the top of the egg mass. The eggs were laid in an oblique position at an angle of about 40° from the side of the hole, the upper end directed toward the posterior portion of the body of the female. They were closely laid and were glued together by means of the fluid into which they were lodged. Similar observations were conducted by Coleman (1911) on the Rice Grasshopper (*Hieroglyphus banian* Fabr.) in Mysore State. The present observations, in general, conform with his descriptions of the manner in which the Rice Grasshopper digs her hole and lays her eggs. The first eggs were laid at the rear portion of the bottom of the hole. From 18 to 34 minutes, with an average of 24 minutes, were spent in laying the eggs (Table 2). From 12 to 32 eggs were found to be laid in each hole. It was formerly reported that female locusts could lay as many as 50 to 80 eggs at one time (Banks, 1922; Anonymous, 1915). No case, however, was noted during the present study where a female locust was able to lay even as many as 40 eggs at a time. Field examination also failed to show an egg pod with more than 32 eggs in it. Judging from the size of the egg-pods (about 3 or 4 cm. in length) and the size of the eggs in it (about 5 mm. in length and 1 mm. in diameter each), it seems hardly possible to find 50 eggs in each pod.

After oviposition, the insect stayed for from 2 to 4 minutes with an average of 3.25 minutes (Table 2) to cover the hole with soil particles. This was done with the hind legs assisted occasionally by the middle legs. She then left the spot and started to feed at once. The total time, therefore, required by the female locust to dig the hole and lay her eggs varied from 48 to 72 minutes, with an average of 57.33 minutes (Table 2).

There were a few cases observed where a male mounted the female while she was laying. Some advanced the suggestion that the male probably helps in the digging of the hole by adding its weight to the pressure exerted by the female. The suggestion, however, does not seem to be based on actual observa-

tions; for, in the majority of cases, a female can bore the hole without a male on her back; also, males which were observed to be on top of the female during oviposition did nothing more than exhibit signs of being in the act of copulation: twisting the abdomen below that of the female and executing the same jerking motions as when they were in copula. But in all cases the female seemed not to mind the male. These manifestations on the part of the male are but signs of sexual desire for, as Uvarov (1928) reported, it pairs with the female immediately after oviposition is complete. However, no case of this kind was observed in the present study.

Laboratory observations showed that a female locust was able to lay as many as five egg-masses during her lifetime with an interval of from 6 to 9 days between two successive layings. The total number of eggs laid by a female, therefore, may reach as many as 70 or even more. It was observed that the first masses laid by a female contained more eggs than those laid later and as more egg-masses were laid their contents gradually became less in number.

The number of eggs laid by one female at a time was determined by digging out egg-masses both in the field and in the laboratory and counting the eggs in each. Of course, the total number of eggs laid by one female was determined in the laboratory only, where a female was confined in the battery jar and every time she laid, she was transferred to another jar and the eggs she laid were dug out and counted. This was done until the death of the insect. The maximum number of eggs laid by a female in the laboratory was found to be 68.

The period of fecundity of the female locust varied from 1 to 37 days with an average of 13.14 days (Table 3) and was found to cease 4 to 36 days before she died (Table 1).

TABLE III.—*Copulation and fecundity of "Pachytylus migratorioides" R. and F.*

Female number	First eggs laid	Last eggs laid	Period of fecundity
	1929	1929	*Days*
1	22–I	7–II	16
2	19–I	25–II	37
3	27–I	27–I	1
4	29–I	10–II	12
5	31–I	12–II	12
6	26–I	4–II	9
7	4–II	9–II	5
Minimum			1
Maximum			37
Average			13.14

Descriptions of different stages—Egg (*Plate I, fig. 1*).—The eggs are subellipsoidal, with the surface slightly sticky when newly laid. They are creamy or light brown, semitransparent, soft, and measure about 5 millimeters long and about 1 millimeter in diameter. Mature eggs are darker and the form of the young nymph can be detected from the outside.

Nymphs (*Plate I, figs. 2–6*).—The locust nymph molts five times, the fifth being the transformation of the mature nymph into the adult form. When newly hatched and while still inside the burrow where the eggs were laid, the nymphs are light gray, the body bent ventrally with the antennae and anterior and middle legs and femora of the hind legs directed postero-ventrally; the hind tibiae are directed antero-medially. The insects measure about 8 millimeters in length and 3 millimeters in width. Once out of the hole they turn white, but later turn brown. Oblique dark brown lines are present on either side of the head and thorax, and across the eyes, meeting at the front. A middorsal longitudinal crest extends from the front to the last abdominal segment. The dark lines passing through the eyes meet at this crest posteriorly at about the middle of the prothorax, while those passing across the genae pass below this line at the mesothorax and metathorax and then fade. The thoracic and abdominal sternites are generally darker than their corresponding tergites. Mature nymphs are generally light yellowish-brown. The vertex and eyes are dark brown, the pronotum black with light grey posterior margin. Legs are of same color as body with hind femora lighter; black markings are present all over. The spines are black. Beginning with the fourth instar, the wingpads assume an upturned or inverted position so that their outer surfaces in the preceding instars become the inner ones in the new position, and what now appear on the outside were formerly those facing the body of the insect. The wingpads of the mesothorax are naturally brought beneath those of the metathorax. The nymphal wing venation become more in evidence. The abdominal pleurites are black toward their ventral border and lined with a single series of white elongate spots, one in each segment; their dorsal borders are light grey on the anterior half of the abdomen but merges into a mixture of grey and dark brown areas posteriorly. The abdominal tergites are black with a longitudinal mid-dorsal yellowish brown line up to the seventh segment. The mature nymph of the last or fifth instar measures about 34.9 millimeters long and 7 millimeters wide.

The duration of the different nymphal instars (Table 4) is as follows:

First instar	7 to 21 days;	average,	16.00	days
Second instar	5 to 21 days;	average,	7.76	days
Third instar	7 to 11 days;	average,	8.40	days
Fourth instar	8 to 12 days;	average,	9.72	days
Fifth instar	9 to 13 days;	average,	11.56	days

The following key has been prepared to show the different stages of the nymphs of *Pachytylus migratorioides* R. and F.

Key for determining the nymphal instars of "Pachytylus migratorioides" R. and F. (refer to Plate II)

Wing pads inconspicuous extension of mesothorax and metathorax with simple elevated network. Directed latero-ventrally..... 1st instar.

Wing pads more produced; directed postero-ventrally.

Tips directed more ventrally than posteriorly. Anterior margin concave, posterior margin convex..... 2nd instar.

Tips directed more posteriorly than ventrally. Anterior margin convex; posterior margin either slightly concave or straight.. 3rd instar.

Wing pads upturned so that those of the mesothorax are beneath those of the metathorax.

Tips of wing pads never reach third abdominal segment..... 4th instar.

Wing-pads always extend beyond second and may reach as far as fifth abdominal segment ..... 5th instar.

Adults (*Plate III, figs. 1 and 2*).—The males are generally smaller than the females, measuring about 41.4 millimeters long and 8 millimeters wide, while the latter measure about 48 millimeters long and 10 millimeters wide. The males are generally yellow or yellowish brown while the females are of chocolate brown color, or generally darker.

Male genitalia (*Plate IV, fig. 2*).—Occupy last four abdominal segments. Penis composed of a pair of tube-like structures inclosed in a thinly chitinized sheath which is open at the tip; distinctly curved dorsally; subequal to coxale in length; width at base about one-seventh length; attenuate distally; surface of tip rugose, more refined basally. Dorsal to it is a pair of elongate, pointed chitinous sheets which are about three-fifths as long as penis. Anterior to penis is a sac-like structure, thingly chitinized and extends as far anteriorly as anterior third of eighth abdominal tergite. At about middle of ninth abdominal tergite are two pairs of heavily chitinized hooks two directed anteriorly, the other two directed posteriorly.

Female genitalia (*Plate IV, fig. 3*).—Ovipositor occupies last three abdominal segments; composed of three pairs of valves: dorsal, inner, and ventral. Dorsal valves (*dv*) subequal in length to abdominal tergites 8 + 9 + 10; greatest thickness

slightly less than one-third length; knobbed at proximal end; distal end pointed and directed dorsally. Ventral valves about four-fifths dorsal valves in length; width about one-eighth length; proximal end broadly concave to fit knob of dorsal valves, distal end cycle-shaped with point directed ventrally. Inner valves small, spear-shaped; length about one-third that of ventral valves; width about one-third length. Dorsal and ventral valves heavily chitinized with surface rough; inner valves more thinly so with surface more even.

The male locust lives for from 23 to 91 days, with an average of 59.5 days, while the female lives from 16 to 95 days, with an average of 68.45 days.

TABLE 1.—*Copulation and fecundity of "Pachytylus migratorioides" R. and F*

Number	Emerged	Copulated	Period between emergence and first copulation	Laid	Period between first copulation and first laying	Died	Period between last-laying and death of female	Total number of copulation	Total number of oviposition
	1928	1929	*Days*	1929	*Days*	1929	*Days*		
	14–XII	12–I	29	22–I	10				
		25–I							
		28–I							
1		30–I		31–I				7	3
		2–II							
		4–II							
		5–II		7–II		11–II	4		
	17–XII	8–I	22	19–I	11				
		26–I		27–I					
		28–I							
		2–II		4–II					
2		4–II							
		8–II						9	5
		11–II							
		12–II							
		13–II		17–II					
				25–II		20–III	23		
	19–XII	14–I	26						
3		26–I						3	1
		27–I		27–I	13	31–I	4		
	19–XII	22–I	34						
4		25–I		29–I	7				
		30–I		4–II				4	3
		7–II		10–II		18–III	36		
	25–XII	23–I	29						
		25–I							
		30–I		31–I	8				
5		1–II						7	3
		2–II							
		5–II							
		6–II		7–II					
				12–II		27–II	15		
	21–XII	17–I	27	22–I	9				
		27–I							
6		1–II						5	3
		2–II							
		4–II		4–II		6–III	30		
	29–XII	28–I	30						
		1–II		4–II	7				
7		5–II		7–II					
		8–II		9–II				5	4
		11–II		10–II		2–III	20		
Minimum			22		7		4	3	1
Maximum			34		13		36	9	5
Average			25–29		9.19		18.86	5.71	3.14

TABLE 2.—*Time spent by the female locust during oviposition*

Female number	Date of laying	Commencement of digging hole	Time completed	Time consumed	Laying started	Rest between digging and laying	Laying completed	Time consumed	Time left	Time from digging to completion of oviposition	Time spent in covering the hole
		p. m.	*p. m.*	*min.*	*p. m.*	*min.*	*p. m.*	*min.*	*p. m.*	*min.*	*min.*
1	26- I-29	30	8.55	25	8.58	3	9.15	20	9.22	52	4
2	4-II-29	3.11	3.34	23	3.39	5	3.57	18	3.59	48	2
3	4-II-29	8.07	8.34	27	8.42	8	9.16	34	9.19	72	3
4	7-II-29	5.06	.....	.....	.....	.....	6.32	.....	6.36	.....	4
Minimum	.....	.....	.....	23	.....	3	.....	18	.....	48	2
Maximum	.....	.....	.....	27	.....	8	.....	34	.....	72	4
Average	.....	.....	.....	15	.....	5.33	.....	24	.....	57.33	3.25

TABLE 4.—*Life history of "Pachytylus migratorioides" R. and F*

Culture number	Eggs laid	Eggs hatched	Incubation period	First molt	Duration of first instar	Second molt	Duration of second instar	Third molt	Duration of third instar	Fourth molt	Duration of fourth instar	Fifth molt	Duration of fifth instar	Duration of nymphal stage	First eggs laid	Duration of life cycle
	1929	1929	*Days*	1929	*Days*	1929	*Days*	1929	*Days*	1929	*Days*	1929	*Days*	*Days*	1929	*Days*
1	26-I	2-II	14	16-II	7	2-III	14	9-III	7	20-III	11	2-IV	13	52	male	.....
2	26-I	9-II	14	17-II	8	27 II	10	8 III	9	17-III	9	29-III	12	48	male	.....
3	26-I	9 II	14	17 II	8	1-III	12	9-III	9	21 III	12	1-IV	11	52	10-V	105
4	22-I	15-II	24	1-III	14	8 III	7	16-III	8	27-III	11	8 IV	12	52	14 V	112
5	1-II	15-II	15	24-II	9	4-III	8	12-III	8	21 III	9	31-III	10	44	Died	6 IV 29
6	1-II	15-II	15	24 II	9	1 III	5	8-III	8	17 III	9	29 III	12	43	male	.....
7	1-II	15-II	15	24 II	9	3-III	7	11-III	8	21-III	10	31-III	10	44	male	.....
8	1 II	15-II	15	23-II	8	3-III	8	11-III	8	20-III	9	29 III	9	42	9-V	98
9	1-II	15 II	15	24-II	9	3-III	7	11-III	8	19 III	8	30-III	11	43	male	.....
10	1-II	15-II	15	24 II	9	4 III	8	12-III	8	21 III	9	3 IV	12	47	6 V	95
11	1-II	15-II	15	23-II	8	3-III	8	11-III	8	22-III	11	3-IV	12	47	10-V	99
12	1-II	15-II	15	23-II	8	3-III	8	12-III	9	24-III	12	3-IV	10	47	12 V	101
13	4-II	26-II	22	9 III	21	16-III	7	27 III	11	6-IV	10	18 IV	12	61	male	.....
14	4-II	26-II	22	9-III	21	16-III	7	25-III	9	5-IV	11	15-IV	10	58	20-V	115
15	4-II	24-II	20	2-III	16	11-III	9	18-III	7	28-III	10	10-IV	13	55	male	.....
16	10-II	28-II	18	9-III	9	17-III	8	25-III	8	4-IV	10	15-IV	11	46	male	.....
17	?	6 III	?	14-III	8	23-III	9	31-III	8	10-IV	10	23-IV	13	48	male	.....
18	?	6-III	?	15-III	9	24 III	9	4-IV	11	12 IV	8	24-IV	12	49	male	.....
19	?	3-IV	?	16-IV	13	23-IV	7	2-V	9	11-V	9	23 V	12	50	male	.....
20	?	3-IV	?	16-IV	13	22-IV	6	1-V	9	11-V	10	22-V	11	49	25-V	?
21	?	3-IV	?	12-IV	9	19-IV	7	27-IV	8	6-V	9	18-V	12	45	male	.....
22	?	3-IV	?	16-IV	13	21-IV	5	29 IV	8	8-V	9	20-V	12	47	male	?
23	?	3-IV	?	12-IV	9	17-IV	5	25-IV	8	3-V	8	16-V	13	43	24-V	?
24	?	3-IV	?	12-IV	9	18-IV	6	25-IV	7	5-V	10	16-V	11	43	male	.....
25	?	3-IV	?	12-IV	9	19-IV	7	28-IV	9	7-V	9	19-V	12	46	24-V	?
Minimum			14	.....	7	.....	5	.....	7	.....	8	.....	9	42	.....	95
Maximum			24	.....	21	.....	14	.....	11	.....	12	.....	13	61	.....	115
Average			16.75	.....	16	.....	7.76	.....	8.4	.....	9.72	.....	11.56	48	.....	103

TABLE 5.—*Longevity of adult male locust*

Culture number	Date emerged	Date died	Longevity
			Days
1	21-XII-28	11-II -29	52
2	21-XII-28	13-III -29	82
3	26-XII-28	8-III -29	72
4	17-XII-28	4-II -29	49
5	24-XII-28	31-I -29	38
6	18-XII-28	27-II -29	71
7	2-IV -29	12-IV -29	71
8	29-III -29	11-V -29	43
9	29-III -29	21-IV -29	23
10	31-III -29	15-VI -29	76
11	30-III -29	29-VI -29	91
12	18-IV -29	9-VII -29	72
13	10-IV -29	5-VI -29	56
14	15-IV -29	23-V -29	38
15	23-IV -29	22-VI -29	60
16	24-IV -29	1-VII -29	68
17	23-V -29	15-VII -29	53
18	18-V -29	29-VI -29	42
19	20-V -29	15-VIII-29	87
20	16-V -29	1-VII -29	46
Maximum			91
Minimum			23
Average			59.5

TABLE 5*a*.—*Longevity of adult female locust*

Culture number	Date emerged	Date died	Longevity
			Days
1	14-XII-28	11-II -29	59
2	17-XII-28	20-III -29	93
3	19-XII-28	31-I -29	43
4	19-XII-28	18-III -29	89
5	25-XII-28	27-II -29	64
6	21-XII-28	6-III -29	75
7	29-XII-28	2-III -29	53
8	23-XII-28	17-III -29	84
9	23-XII-28	20-III -29	87
10	1-IV -29	26-V -29	56
11	8-IV -29	26-V -29	48
12	31-III -29	16-IV -29	16
13	29-III -29	16-VI -29	79
14	3-IV -29	4-VII 29	92
15	3-IV -29	30-VI -29	88
16	3-IV -29	7-VII -29	95
17	15-IV -29	2-VII -29	78
18	22-V -29	14-VII -29	53
19	16-V -29	14-VII 29	59
20	19-V -29	5-VIII 29	78
Maximum			95
Minimum			16
Average			68.45

BEHAVIOR OF THE LOCUST IN ITS DIFFERENT STAGES

Behavior of the nymphs.—The nymph, after hatching from the egg-shell, rests a little and then wriggles its way to the surface of the ground. Once out of the hole it will me noticed that it is still enveloped in a thin, semitransparent membrane and that it lies on its side wriggling violently until this membrane is

broken up and it frees itself. This act of shedding the membrane is termed by Uvarov (1928) as the intermediate molt of the nymph. Immediately afterwards, the membranous covering thus shed contracts into a tiny crumpled mass which immediately turns white. This material is very light and may be blown away by a slight breath. There were cases in which this envelope was not completely removed, hence it remained attached to the body of the hopper—either to the head, leg, abdomen, or any other part where its complete separation from the body did not take place. Upon the first molt, however, it was removed with the axuvia.

The nymphs immediately move about the opening of the hole but do not go far. They are creamy white, some retaining a slight tinge of the grey coloring. When disturbed at this stage, they are able to make several jumps before they finally get tired and rest. Normally, however, they do not move about very far until their bodies are hard enough to sustain injuries. In the meantime, the color gradually turns to dark brown with the markings described above becoming more prominent. Later, they move about still farther until nymphs or hoppers hatching from different egg-clusters come together making the swarm bigger and bigger. They become more active as they grow older; hence they can travel longer distances per day. It was observed that hoppers select the clear ground where there is little or no vegetation growing and where they are exposed to direct sunlight. Here they congregate in groups until late in the afternoon when they begin to climb grass blades where they pass the night. The migratory instinct of the hoppers is much more in evidence about the latter part of the morning towards noon and early in the afternoon, during sunny days. It is during this time of the day that they travel fastest. The young hoppers do not feed much or, for the first few hours do not feed at all. Newly hatched nymphs do not do much damage; but as they progress in their development, their feeding activities increase and the ravages they cause become correspondingly greater. In their earlier stages of development the hoppers start to feed on the sides of the grass blades without touching the midrib. But as they advance in their third stage, they are able to cut across a leaf. Fourth and fifth stage hoppers can eat a whole lot and there were numerous cases where entire portions of the grasses or rice above the ground were eaten up. In case of plants where other portions than leaf blades are hard

as in the case of corn, sugar cane, or coconut, only the midrib of the leaves and the stalks are left during serious infestations (Plate V).

Molting.—When molting, the nymph always stays suspended on a grass blade or leaf of a shrub, with the head hanging down. Molting is essentially the same in all the nymphal instars, the only difference in the last molt from the earlier ones is the development of the wings of the adult individual. When the full grown hopper (fifth instar) is ready to molt for the last time, it assumes an inverted position, as in the earlier instars, with the head directed downward, suspending itself on the blade or twig by means of its hind and middle legs and in some instances even with the aid of the front legs. The insect stays motionless for some time, when finally the wingpads are gradually spread apart and the notum broadens as if from some internal pressure. Slight lateral motions of the body are evident. The result of these continuous motions is the splitting of the old skin of the notum longitudinally in the middle. First the mesonotum and the metanotum split and then the pronotum follows. The notum of the adult locust is then exposed. While the new insect forces its way out through this slit, the old skin of the head also breaks off, the slit being the extension of that of the old notum. This slit on the head extends as far as the vertex. This extension of the opening facilitates the emergence of the new form. The head is forced out completely first, then the first two pairs of legs followed by the wings and the hind legs. For some moments, and while the posterior portion of the abdomen is yet within the old skin, the insect remains suspended and motionless. The new set of wings are almost equal in size; they are short being slightly longer than the nymphal wing-pads. They are soft, hence their tips hang down.

The weight of the insect itself forces the rest of the body out. But before the tip of the abdomen emerges from the exuvia, the adult locust crawls around so that its head points toward the tip of the blade of grass on which it molts. This sets its whole body free. The insect spends about fifty minutes from the time it settles to molt up to the time that the whole exuvia is cast off.

In this new position the tips of the wings are turned towards the posterior portion of the abdomen. They are very light yellowish brown. They are fleshy and much thicker than the normally fullgrown wings. Darker brown tracheate ramifications

are evident. Heaving motions of the adult locust can be detected at intervals. These apparently create internal pressure which are conveyed to the wings; for each time the insect heaves the wings expand until their full size is attained. The hind legs help in this process by rubbing the wings gently each time they increase in size, as if to stretch them and put them in position.

From emergence, it takes about 30 minutes for the wings to assume their normal size.

But this is not yet the end. The hind wings are still expanded like two plain substriangular sheets. After the normal size of both wings is reached, the insect rests for a few minutes, apparently waiting for them to dry. All of a sudden the forewings are slightly raised and the hind wings with the aid of the hind legs are gradually folded beneath the forewings in their normal position. This last step consumes about eight minutes.

When, however, the wings dry out before they reach their full size, the insect is doomed to remain thus crippled for life, unable to fly. Legs also may be twisted and harden thus, so that the locust remains unable to walk. There are also many cases in which moltings can not be completed; hence adult locuts move about with the old exuviae still attached to them.

The newly emerged adult first isolates itself from the others and whenever approached by chance tries to keep the intruder off by the use of its hind legs, or else evade it by simply moving away as fast as it can.

Behavior of the adults or fliers.—Newly emerged fliers first hover around the area of infestation without following any definite direction. Later, however, they start on a more prolonged flight, in a more definite direction. If they happen to go against a strong wind, the swarm is put to disorder and the fliers alight on the ground or fly low around the place until the wind calms down, when they will mount higher again and resume their frustrated flight.

These adults go in large swarms and migrate from place to place, often covering a considerably long distance in one continuous flight. Although different interpretations have been advanced as to the possible causes of the emigrations of these insects from their breeding grounds (Uvarov, 1928), this question has not been included here as the time spent in the present study was quite insufficient to include a thorough survey of the behavior of locust swarms in the field. This phase of the locust

problem will be dealt with separately and more in detail later. In this connection, however, a few interesting, though sketchy, observations on the behavior of the insect may be cited.

It has been observed that during rainy or cloudy days, the locusts are very inactive. They remain concealed among the bushes and except when feeding, very seldom, if ever, move. They can be approached without showing any sign of alarm. On the other hand, during bright, sunny days, these insects are very active from early in the morning to late in the afternoon. They cannot be approached without their showing great agitation. This is true with both the hoppers and the fliers. In several instances observed, it was the tendency of the insects to move toward the source of light and for that matter also heat. In our multiplication cage in Alabang, for example, adults and hoppers of the migratory locust remained concealed in bushes or corners of the cage until about 7 o'clock in the morning when they would start to move about. It was observed that the majority of them stayed on the east side of the cage. In the afternoon, however, they would be found to be moving toward the west side. Many times also in the field, the same phenomenon was observed. Most swarms of hoppers move toward the east in the morning and toward the west in the afternoon. Also, as just stated hoppers select the clear portions of the ground where they can get the greatest amount of light or maybe because these clear portions are more attractively bright than those darkened by vegetation. Again in our observation cage, during cloudy or rainy days, the locusts were not noticed to be exhibiting any marked degree of activity. They were often found beneath the bushes and in corners of the cage. Those found among the plants were seldom seen feeding. While all these tend to show that the locusts migrate in the direction of the greatest intensity of light and heat, except in some instances when their progress is impeded by some natural barrier or by locust fighters, yet we cannot attribute these activities to these two factors alone. There may be still other factors which may influence migrations, and as Uvarov (1928) stated, migrations may be due to some internal or physiological factors. As has been stated, this problem will be taken up more fully later.

Adult locusts are more voracious than hoppers in most instances. They are able to eat considerable quantities of vegetation and in serious cases can completely destroy whole fields planted to rice, corn, or sugar cane (Plate V). Rice grains in their early stage of development are likewise devoured by the

adults with great rapidity. When hungry, it seems as if the locusts are not "choosey" as to the food they eat. Once they alight on a plant, they start feeding at once and do not cease until fully satisfied, seldom, if ever, leaving the spot where they first alighted.

A mature locust weighs approximately 3 grams; the progeny of one locust in the fourth generation would be nearly 5 tons of locusts. As each locust consumes approximately 300 times its own weight in food, the progeny of one locust in the fourth generation would consume some 1,500 tons of vegetation which, is the case of young maize, cane, or rice, would make a few fields at least look *rather bare.*

Even admitting the above to be overestimated by 50 per cent, it can be readily imagined what the progeny of one of these vast swarms, which sometimes appear, would be if allowed to reproduce quite free from all natural checks; * * *." (Mackie, 1913.)

THE THEORY OF LOCUST PHASES

Quite recently, there appeared a report of the discovery of different phases undergone by the migratory locust (Uvarov, 1921–22; 1928). Otanes (1927) has already called attention to this and other papers (see abstracts in "Biological Abstracts," Vol. 5, 1931, No. 1, p. 179). It has been alleged that the species of locust we have here is a form of the species of locusts in Southern Europe (*Locusta migratoria,* L.) in the region of the Caspian Sea, which was observed to undergo two distinct forms or types. One was the solitary type (ph. *danica*) and the other was the migratory type (ph. *migratoria*). The former was described as being generally green, in contrast with the migratory type, which is generally reddish or yellowish brown. Detailed descriptions of each form were given to show that they really belonged to two different types. But breeding experiments by Plotnikov (1924) revealed that under certain circumstances, one form may give rise to the other. The green type was not observed to cause any appreciable damage to crops.

In this connection, a very interesting case was observed with the Philippine migratory locust in our laboratory at Alabang. In about the latter part of June, 1929, there were caught around the laboratory, green locusts of the same size and form as the migratory species. These were confined in a separate cage. Several green hoppers from the same locality were caught in addition, and these were confined in another cage. The hoppers, upon emergence, proved to be the same as the adult green forms and so were transferred to the cage of the latter. Two females emerging from these hoppers were isolated in another cage

for reasons to be mentioned later in connection with the transformation of two male migratory locusts into green ones. The male and the female have essentially the same color patterns. The following is the description of the coloration of this form:

Head, thorax, and femur of hind legs, green. Vertex, genae, green; frons and clypeus, greenish yellow; labrum, greenish brown; eyes, brown; base of mandibles, brown, middle portion bluish, tips metallic black. A yellowish brown band, bordered on either side by brown ones, extends posteromesally from back of eyes to occipital region of head. Proximal half of antennae light yellowish brown; distal half, brown. Pronotum and propleuron, green; prosternum, light brown; median longitudinal crest on pronotum, brown with two longitudinal diffused brown areas on either side; transverse light yellowish brown area present on each propleuron with a dark brown patch in the middle. Mesopleuron and metapleuron, green; mesonotum, greenish brown; metanotum, brown; mesosternum and metasternum, brown. Mesothoracic leg, brown. Femur of metathoracic leg, green with brown patches on ental surface; tibia, yellowish brown; tarsus, darker than tibia. Mesothoracic wings brown; metathoracic wings, brown at costal region and at distal two-thirds of apical region, yellowish green at anal region. Abdomen, greyish brown with yellowish brown band along entire length of ventral border or pleurites; abdominal sternites, lighter in color than tergites. Not much anatomical difference was noted except the absence in the green type, of the constriction of the pronotum which is present in the migratory species. Instead, this part was somewhat elevated from the level of the head and silghtly arching on its posterior two-thirds.

These locusts were allowed to lay eggs in the cage and on August 10, 1929, hoppers emerged. Seventeen hoppers in all were counted from one egg-mass. Strange to say, these newly hatched hoppers resembled those of the migratory species in all the arrangement of color patterns, except that generally these progeny of the green locusts were lighter in color than those of the migratory.

Again, on July 16, 1929, two male locusts in our multiplication cage at Alabang, were observed to have turned green. These were caught, and when compared with the green locusts caught in the field near the laboratory, were found not to differ very much in color patterns. The constriction on the pronotum, however, remained. These males were confined in a cage and in the absence of green specimens from the female members

of the migratory species, two newly emerged females from our green locusts caught outside were confined with them.

On July 20, 1929, a couple was found in copula. They were at once segregated from the rest and confined in a glass jar with soil and feed given them from time to time. The female laid her first mass of eggs on July 31, 1929. These eggs were hatched on August 15, 1929, the hoppers resembling those of the pure migratory type more than they did the hoppers of the green type. The older these hoppers grew, the more they resembled those of the migratory species.

Again, out of twenty individual cultures in our latest life history studies of the migratory locusts, ten turned green during their nymphal development, and the rest either retained their original migratoid color or assumed some other shades closely resembling the floor of the cages in which they were confined. The green hoppers were like those caught outside in all color patterns.

Specimens of this kind were also collected from Los Baños, Laguna, just north of the College of Agriculture grounds, and from Talavera and Muñoz, Nueva Ecija. Each of these specimens collected in the fields were found in isolated spots. None were found in large groups.

This part of the life of the locust has not been dealt with more seriously in the present work as its importance requires a more thorough study and therefore much more time is needed. The foregoing observations, however, tend to show that the Philippine migratory locust is capable of assuming different degrees of coloration, when isolated individually to correspond to that of their surroundings. When out in the field, they generally acquire the dominating color of the immediate environment—grass. When confined together, however, as was done with the progeny of the green specimens caught outside of the laboratory, in which all hoppers hatched from different egg-masses were confined together in a big cage, the green color did not show up. Instead, they assumed the color of the migratory species, only somewhat lighter. Whether or not the isolated cases of green locusts are what correspond to Uvarov's solitary phase cannot yet be determined. A separate study of this question will have to be made.

CONTROL MEASURES

The methods here given have been in use in the Islands since the early history of locust infestations and the most effective

of them were gradually improved through careful observations and experimentations. It is hoped that better control measures will be discovered in the future, which will prove a permanent weapon against this pest.

The common native control measures employed against the Philippine migratory locusts consist of digging out and destroying the eggs, driving hoppers into pits, netting, burning and using insecticides (spraying and dusting).

DIGGING OUT EGGS

Digging out the eggs is very simple but tedious work and requires a great amount of labor. Whenever practicable, however, this method should be resorted to, until a more practical means of destroying egg deposits is discovered. It must be remembered that a mass of eggs destroyed means about 40 locusts killed in a comparatively short time. When labor is cheap, paid labor should be employed.

A case in point occurred (during the writer's administration as Director of Agriculture for Mozambique) in the Zambasi district in 1909. Some 17 tons of migratory locust eggs were dug up by cheap native labor (mostly women and children) within the space of some 100 hectares on a sugar plantation in about two weeks time—this constituting what will probably long remain the world's record for locust-egg destruction by hand. (Barrett, 1913.)

Plowing the ground where egg deposits are located has been suggested (Hobart, 1909), but only a small percentage of the eggs are destroyed in this way. Only those egg masses through which the plow cuts are crushed, while those that remain intact in the clods or sods are not affected. Exposed eggs are also subject to the attack of enemies, especially birds and ants. It has been experienced also, that locust eggs in their advanced stages of development continued to grow and hatched even when they were removed from the cluster and scattered on the surface of the soil, except where the sun was hot, in which case the eggs dried up. Besides these disadvantages, the method has a very limited application, and considering that a great majority of locust swarms lay their eggs in thick cogon areas and in almost inaccessible places, it cannot at all be recommended. In fact, this means of egg destruction is seldom used now-a-days by farmers unless eggs are laid in areas that will have to be cultivated anyway.

PIT OR DRIVING METHOD

The commonest and so far the most effective method of killing the nymphs or hoppers is the pit or driving method (Plate VI). This can best be employed on level ground or where the grass and shrubs are not so tall as to render driving difficult. Native farmers are generally familiar with this method so that it can readily be executed at the time an infestation is noticed.

The materials necessary for this work are galvanized iron sheets, about 25 cm. wide; mattocks, spades, and crowbars with which to dig the holes into which the hoppers are to be driven and branches of shrubs or trees with which to drive them.

The pit should be dug some 8 or 10 meters in front of the advancing swarm of hoppers. It should be about a meter cube. or it can be made cylindrical with a diameter of about one meter. The sides should be lined with galvanized iron sheets to prevent the hoppers from climbing to the surface. From this hole the iron sheets should be laid lengthwise in a vertical position, in the shape of a V with the hole at the vertex and the opening towards the insects. Hooked pegs should keep the sheets upright. These pegs should be driven outside, with the hooks toward the interior of the V, to keep the hoppers from using them as a means of reaching the top of the sheet and eventually escaping. The back part of the pit should also be lined with iron sheets of the same height as the ones already set on the ground.

As soon as all these preparations are made, the campaigners should form a line behind the swarm with each holding a branch of a tree or shrub with leaves. They should move slowly forward swinging their branches sidewise, making just enough noise to keep the insects moving steadily forward. This work should be done as steadily and patiently as possible, as a slight disorder, such as beating the ground hard with the branches in an effort to frighten the hoppers so they may move toward the pit faster, or other extraordinarily loud noise, may throw the swarm into disorder thereby causing many of them to jump in all directions and some to go back in spite of the men behind. This will spoil the whole thing and much time will be lost and many of the locusts will escape. If the swarm is so big that the hoppers at the end get so tired before reaching the pit so that they will not move farther forward, the campaigners must not

force them to move by rushing forward themselves, as this will only cause these members of the swarm to be left behind. The best thing to do is to stop also without stopping the swinging of the branches, and it will be noticed that within a short time afterwards, the hoppers will regain enough strength to move forward once more. Hoppers, especially those in the first to third instars, get tired very easily when made to move through excitement like being driven or being caught; therefore, they should be given time to rest when necessary. In fact, this method ought not to be used with hoppers in the first stage as these do not form bands and do not move much from the region where they were hatched.

If the locust-chasers are few so that they cannot cover the entire width of the swarm, a long rope may be used and branches with leaves tied at intervals to it. This rope can be moved so that the branches swing slowly sideways. Men should also be stationed on either side of the swarm to keep any from escaping on either side. Once in the pit, the hoppers should be destroyed, either by crushing or by spraying them with soap solution. When the swarm is too big for the hole, the hoppers should be removed as fast as the hole gets filled up and put in sacks and these securely tied up and dipped in boiling water to kill the insects. These dead locusts should be buried deep to prevent rotting on the surface of the ground, or eaten or fed to the chickens or pigs.

More recent field observations in Isabela and Cagayan, showed that at a certain time of the day, a band of hoppers traveled in a certain definite direction and followed that course until a considerable distance was covered. In some cases, bands of hoppers went in only one direction for the whole day. Sometimes barriers may change this course or when the band is disturbed, the hoppers will disperse in all directions. Taking advantage of this finding, we can dispense with the greater number of the campaigners in any one place. The pit should be dug and the iron sheets laid as directed, at such a rate that the whole work will be completed before the head of the approaching band is near enough to be distributed by the workers.

As soon as everything is completed, the men should move away from the pit so as not to scare the hoppers away. Nobody needs to drive the hoppers as they will continue their course toward the pit into which they will fall. All that the campaigners have to do is to kill the hoppers in the pit. This method is also fully discussed by Uvarov (1928).

NETTING

This method can be employed both against the hoppers and the fliers. The net against the hoppers has a somewhat semicircular rim and can be used to advantage only on level ground. The straight side of the rim of the net is placed against the surface of the ground with the rest of the rim arching above it. The hoppers are then driven into this net and destroyed. When swarms are located near the roads, there is a great tendency for the hoppers to cross the street. During this time the type of net described above can be used to the best advantage. This method of catching the hoppers is rarely used and in fact has been seen only in Cagayan. It cannot be recommended even on level ground, as the size of the net is not enough to catch an appreciable part of the swarm. Besides, the nets themselves and the men behind them are enough to scare the hoppers away.

Nets with circular rims and mounted on handles are used to advantage in catching fliers, either in flight or at rest (Plate VII).

BURNING

When the hoppers are located in a place covered with plenty of dry materials, it is advisable to set fire to these materials to burn the hoppers. Care should, however, be taken that the fire does not go beyond the infested area. Needless to say, this method is applicable only in places where there is no standing crop that might be burned, or where dry materials to be burned are available.

When an egg deposit is located in a noncultivated area, and whenever practicable, dried materials should be scattered on the ground and upon the hatching of the eggs, these should be set on fire to burn newly hatched nymphs.

Fliers are said to be attracted by light, so that one way to kill them is to build bonfires at night (Hobart, 1909). This will reduce the size of the swarms to some extent.

CONTACT INSECTICIDES

SOAP SOLUTION

Locust hoppers and adults may be killed either by contact sprays or by stomach poisons. Of the many experiments with different contact insecticides tried by the former Bureau of Agriculture for a number of years, the ordinary yellow Chinese laundry soap dissolved in water has been found to be the

simplest to prepare and also the most effective against hoppers in all stages and also against the fliers (Otanes, 1923). The soft-soap solution, therefore, has been adopted for the last few years. This soap, dissolved in water at the rate of 0.4 to 1 kilo in about 20 liters of water, has been found to be a deadly contact poison to locusts; for it clogs up the breathing pores or spiracles of the insects and thus kills them in a few minutes.

Amount of soap to use.—For hoppers and fliers 0.4 kilo to 1 kilo of soap should be dissolved in one petroleum canful of water (approximately 20 liters). Cut the soap into small pieces and put these in the can of water. Heat the water to boiling or until all the soap is dissolved.

How and when to spray.—The solution can be placed in any suitable container, preferably a bucket or a petroleum can. It can be sprayed on the locusts by means of a bucket pump to which is attached a long rubber hose (5 meters or more). To distribute the solution as a fine mist on the insects a Bordeaux or Vermorel nozzle should be used.

Care should be taken that the hoppers are thoroughly wet with the solution, as this ought to reach all the breathing pores of the insects and clog them up completely, so the hoppers will die from suffocation. The best time to spray the hoppers with soap solution is when they are still in the first instar, especially just after hatching, for they do not move much and being all together are easily killed with the solution. If this is done, much time, labor, and expense can be saved as well as crops which would otherwise be destroyed by the locusts if they were allowed to live much longer. For spraying older hoppers, the best time is in the evening when they come to rest; and early in the morning before they start to migrate. Younger hoppers, according to the experience of locust inspectors in the field, succumb readily to soap solution during the hottest part of the day. This is probably due to the corrosive effect of the solution on the body of the insects when hot, coupled by the clogging of the spiracles. Evaporation of the water in the solution leaves a thin layer of precipitate on the body of the locusts which probably covers their spiracles in a comparatively short time during hot days.

Like other remedies, the soap solution has its limitations. For example, it cannot be used during rainy days. The rain will wash away the solution from the body of the insects or it will dilute the solution so much as to render it ineffective. Also, there are places where the water supply is either inadequate

for the campaign, very far from infested places, or entirely lacking. This disadvantage has rendered numerous past campaigns very difficult and often not as successful as anticipated.

SODIUM HYDRATE-RESIN SOLUTION

Goco (1923), in his report on locust sprays, found this solution effective. He gives the following formula:

	Parts
Sodium hydrate (98 per cent)	1
Water	12
Resin	6

According to the stage of the hoppers, the stock solution should first be diluted with from 8 to 16 times its volume of water before it is used.

Toquero (Goco, 1923) found another formula to be also an effective locust spray. He claims that 100 per cent of the insects sprayed died when the operation was performed in the evening. His formula follows:

	Per cent
Resin	1.9
Sodium hydrate	0.95
Petroleum	0.7

These ingredients should be mixed with water to make 100 per cent.

STOMACH POISONS

CALCIUM ARSENATE

Calcium arsenate powder (20 to 30 per cent in air-slaked lime) was found to be a very effective poison for locusts. This is dusted by means of gun-dusters and bellow dusters. This poison is now being used quite extensively against locusts and other pests that go in large swarms. Where the area infested covers several hectares an airplane will be found to be of great use. The Bureau of Plant Industry has been using of late years two airplanes to dust calcium arsenate powder over infested areas.

From 5 to 10 kilos of dust are necessary to spray one hectare of land, depending upon the contour of the field and the height of the grass on which the hoppers feed. Late in the afternoon is about the best time to dust as the locusts then stop traveling for the night and do considerable feeding.

Tests in the laboratory showed that 80 per cent of the hoppers treated succumbed to the poison two days after they had eaten it and at the end of four days and a half 90 per cent of them

had died. Immediate death should not be expected when using this powder as it takes a long time for the poison to kill the insects. Only 10 per cent were killed at the end of one day. Locusts, however, that had eaten the poison do not feed much or in some instances do not feed at all, depending on the amount of the poison taken. So that, after all, there is very little or no danger at all to be feared from hoppers that have taken the poison, although they may live for several days thereafter.

POISONED BRAN BAIT

This stomach poison was found in the laboratory to be an attractive bait for hoppers and is very effective. In fact, it is widely recommended by entomologists in countries where locusts are present. The bait consists of:

Paris green	kilogram	0.9
Rice bran	kilograms	22.7
Lemon	do	14.0
Molasses (cane)	liters	3.8
Water	do	16.0

It is prepared as follows:

The bran and Paris green are mixed thoroughly together. The lemon is chopped up fine after the juice is extracted; and the pulp and the juice are mixed well with the bran-Paris green mixture.

The molasses and water are also mixed and then added, little by little, to the poisoned bran mixture, the whole thing being thoroughly stirred every time a little of the sweetened water is added. This will make a moderately moist mash with an attractively sweet smell. When the weather is hot the molasses may be increased to 4½ liters and the water to 18 liters. The resulting mash will stay moist for some time in hot weather even when left outside. This bait should be scattered at the head of the moving swarm of hoppers and for several meters ahead, late in the afternoon when the insects usually stop to rest and eat.

Laboratory experiments have shown that hoppers in the fourth instar died 24 hours after they had eaten the bait; and at the end of the second day from 70 per cent to 85 per cent of the hoppers treated were dead. The bait seemed to be so attractive to them that even in the presence of rice plants, they attempted in the evening to come down to eat the bait.

Hoppers that had eaten the bait showed signs of sluggishness after 17 hours. They did not move much and could not eat any

more. They hid themselves in dark places especially at the base of grasses and shrubs or sought solitude in the highest portions of grass blades and the foliage of shrubs. They died shortly afterwards.

If there is no lemon, the rest of the ingredients of the above mash may still be used in the following proportions by volume:

	Parts
Paris green	1
Rice bran	50
Molasses	5
Water	10

With this mixture, 80 per cent of the hoppers treated in the laboratory succumbed at the end of the second day.

Wherever this bait is to be applied, care should be taken that domestic animals such as hogs and chickens, are kept away from the treated area as there is danger of their being poisoned.

CONTROL BY MEANS OF NATURAL ENEMIES

One very effective means of fighting the locusts, and for that matter, any other insect pest, is by means of employing their own natural enemies. Like most insects, the locust is subject to the attack of other animals, some of them other species of insects. These enemies, however, seem to be so very few in number that their work is in most instances not evident. Therefore, we must try to discover these enemies of the pest and help them in their multiplication and dissemination. Unfortunately, very little work along this line has as yet been done in the Islands. The time spent in the present study has been quite inadequate to cover this phase of the problem thoroughly. Therefore, what are reported here are but rough observations made during the study of the biology of the insect. This phase, however, together with other methods of control, will constitute the greater part of future studies on the Philippine migratory locust.

The natural enemies of locusts are divisible under three heads: (1) predators, (2) parasites, and (3) diseases.

Predators.—Of the predators we have birds, reptiles, mammals, amphibians, insects, etc.

Among the birds is the martinez (*Acridotheres cristatellus*). This bird is well known here and is often caught and confined in cages in houses. Because of its habits, however, such birds should not be hunted or caged but should be protected and left at liberty.

Another species of bird known locally as *Cabisote, tarat,* or *pakiskis* (Tagalog) eats the locusts with greed. Observations in the laboratory showed that one of these was able to consume at least 60 hoppers in the third and fourth stages in one day. Such birds certainly would prove a great help in reducing a locust swarm before the insects reach maturity, and should not, therefore, be caught and caged or killed. It is a common practice among the natives to set up snares in the fields. This bird usually alights on short poles in barren fields and is, therefore, easily caught in the snare consisting of an erected piece of bamboo tip with a loop attached to a spring below. *Since this device usually catches insectivorous birds its use in catching birds should be prohibited.*

Other birds that are reported to feed on the locust are kingfishers, jungle fowl, or wild chicken, quail, etc. When the infestation is in a populated place the domestic chickens and the turkeys make good enemies of the insects. They devour large quantities of locusts, which food, incidentally, does them good.

The common reptiles observed to feed on the locusts are the different species of lizards and snakes.

Frogs are also known to feed on locusts. These amphibians are habitually insectivorous and when they have the chance, capture and eat a great number of young hoppers.

The foremost mammalian enemy of the locust is of course man, whose motive for destroying the locust is twofold: First, because his crops are damaged to such an extent as to cause him to lose enormous sums of money, and secondly because locusts are good to eat. Several dishes can be prepared from locusts and they are relished very much by many people. Other people, although not in the habit of eating locusts, catch the insects for market. A cavan of locusts sells for as much as ₱15 so that many are eager to follow flying swarms for considerable distances. For example, locust dealers in Bulacan go as far as Isabela and Cagayan to catch locusts and take them to their province or to Manila to be marketed. Female locusts with eggs command higher prices than males.

Other mammals that have been observed to feed on locusts are the wild hogs, rats, dogs, etc.

Cannibalism.—Hoppers exhibit a marked degree of cannibalistic instinct. This is especially apparent during the third and fourth stages of their development. Even at a distance of some 10 to 15 centimeters hoppers are able to jump upon their fellows with the intention of devouring them. If the hopper thus

caught is weak, then it is doomed to be eaten up; but if it is strong enough to escape, then it gets free and moves away. Once a hopper is caught and is unable to escape, about three or four more hoppers come around and help the captor devour its victim. One hopper being feasted upon by four or five other hoppers is a common sight in the field. Molting hoppers are ready victims to this instinct. This habit of this insect keeps them from maintaining their originally enormous number of individuals.

PARASITES

So far only two parasites have been observed in the present study. One is a worm that inhabits the alimentary canal of the locust and the other is a mite that clings on the outside of the body of the insect. The former belongs to the genus of hairworms, *Gordius*. As many as three or four hairworms may be found in a single infested locust and there are many cases in which the locusts so affected die after a certain length of time. This kind of worms lives free in fresh waters and the larvae that hatch from the eggs find their way into the body of the locusts through the vegetation that they eat. The real effect of the presence of these parasites in the bodies of their hosts will be studied more in detail. The species of mite is not yet determined. The presence of this mite, however, seems to have no effect on its host, so that it cannot be considered of much economic importance.

DISEASES

A species of fungus belonging to the genus *Mucor* has been found to cause death to locusts here. This has been observed on the body of a living locust. Its growth was noticed at the base of the antenna and the infested locust was very weak and could not maintain its balance. It died the very afternoon of the day it was caught. A growth of this fungus was also noticed on the notum of the adult locusts infected, at the bases of the wings. Further tests, however, on this fungus using fresh materials of locusts failed to show any marked virulence to warrant considering it effective. It might have been due to unfavorable weather conditions. Similar tests on the same genus of fungus were conducted by Butler and Lefroy (1907) on some locusts found in South Africa. The species of the fungus used was *Mucor exitiosus* Massee. The results, however, did not prove encouraging, as healthy locusts could not be infected through diseased ones. According to the same authors, this fungus was utilized for the destruction of locusts in South

Africa. Further culture and extensive tests of same will be made in connection with our native migratory locusts.

During the earlier part of the study of the life history of the green locusts in the laboratory, a number of hoppers in the second instar were found dead and their bodies covered with a growth of a certain species of white fungus. The hoppers killed were still clinging either to the upper portions of the blades of their grass feed, or at the base of these plants. The fungus [1] was similar to a species of the same name which killed locusts in South America and, according to Prof. Brunner, attacks several species of locusts and is able to resist the wide range of weather conditions (Howard, 1901). The hoppers killed were active the day before they were found dead, which showed that the fungus grows fast and its effect is evident within a very short time. Several adult locust were also found dead in our cultures without any external signs of the causes of their deaths. Upon dissecting, however, it was found that the entire thoracic cavity of many of them was covered with a fungus growth, and when they were laid aside for a day or two, fungus growths were noticed on the outside of their bodies—notably along the different sutures of the thoracic region. A more detailed study of this species of fungus will be undertaken shortly and a report on the results published.

REFORESTATION

The vast grass and cogon areas in many regions of the Islands serve as good breeding places of the migratory locust. In fact numerous large swarms have been observed to have come from such areas. It is therefore suggested that such otherwise unprofitable lands be turned into forests thereby diminishing the possible breeding places for locusts and at the same time making these waste lands profitable (Camus, 1921; Otanes, 1925).

COÖPERATION, AN ESSENTIAL MEANS OF DIMINISHING AND PREVENTING LOCUST INFESTATIONS

In order to effectively combat such a serious and formidable pest as the locust, community effort and assistance must be had. The residents of an infested area must lend their full support to the agents of the Government which, alone, cannot do the work of destroying these insects with marked success.

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[1] In a letter to the writer (dated May 8, 1931) by Mr. Gaudencio Reyes, Phytopathologist of the Bureau of Science, he expresses the belief that the fungus might be *Sporotrichum globuliferum*.

The Third Philippine Legislature, in its third session, enacted a law, Act No. 2472, on February 5, 1915, making the destruction of the locust by the inhabitants of an infested area, compulsory. Among other things, it compels every male inhabitant between the ages of 16 and 60 years, inclusive, to work for the Government, without compensation, 9 hours a day for two days in a week for locust destruction. It created a board in each province known as the Locust Board which "shall keep itself informed with reference to the presence of locusts which may exist or are likely to appear in the province, and on the appearance or prospective appearance being brought to the notice of any member of the board, it shall be his duty to report the same forthwith to the chairman of the board. Upon receipt of such information, the chairman shall either at once convene a meeting of the board or if it appears necessary, depute one or more members of the board to make inquiries, and upon receipt of the report of such member or members, the chairman shall convene the board to take the necessary action for the suppression of the pest and bring such knowledge to the attention of the president of each municipality in his province and to the Director of Agriculture."

Another Act, No. 3163, was passed by the Sixth Philippine Legislature in its second session (March 8, 1924), appropriating the sum of ₱100,000 for compaigns against this pest and to finance research work on the insect. At first, this Act was approved for the year 1924 only, but later Act No. 3217 (1925 Appropriation Act) made this amount a yearly appropriation. This Legislature also passed on March 6, 1924, a law, Act No. 3146, known as the Locust Exterminating Tax. "This Law authorized provincial boards to establish a locust extermination tax, upon recommendation of the Director of Agriculture and provides for the collection and disbursement of the same; establishes penalties for delinquency in the payment of said tax, and authorizes justices of the peace to impose the proper penalty upon delinquents" (Teodoro, 1925).

Under the locust laws, the work of the Bureau of Plant Industry for locust extermination comprises the following main divisions:

a. Extermination of locusts in the populated regions, known as the "General Locust Campaign" (Act 2472); and

b. Extermination of locusts in the isolated places, known as the "Locust Scouting Work" (Act No. 3163).

SUMMARY AND CONCLUSIONS

1. The species of locust under the present study is *Pachytylus migratorioides* R. and F. family *Locustidae*, order Orthoptera.

2. The insect is apparently limited in its distribution to tropical countries. It is widely distributed, at times in the Islands.

3. Considerable damage has been done by this pest to Philippine crops, notably to rice, corn, sugar cane, and coconut.

4. In the laboratory, the locusts began to copulate 22 to 34 days after emergence, the average time being 25.29 days. Males came to sexual maturity earlier than did the females. They copulated from 3 to 9 times with an average of 5.78, during their lifetime. Copulations lasted for from 50 to 110 minutes, and may take place at any time of the day, and in any place.

5. From the first mating, 7 to 13 days elapsed before the first laying took place. A female locust could lay as many as five times during her period of fecundity. Every copulation was not necessarily followed by oviposition.

6. Normally, the eggs were laid in the ground in a hole about 6 centimeters deep. But in certain instances, the females may be forced to lay her eggs in exposed places, as on the leaves of plants and twigs.

7. From 48 to 72 minutes were spent by the female locust in oviposition.

8. From 12 to 32 eggs were found to be laid in each hole. The total number found to be laid by a female during her period of fecundity was 68 eggs at the maximum.

9. The period of fecundity of the locust varied from 1 to 37 days with an average of 13.14 days and ceased 4 to 36 days before she died.

10. The duration of the different stages of the locust were as follows:

Egg	14 to 24 days;	average,	16.75 days.
Nymph, first instar	7 to 21 days;	average,	16.00 days.
Nymph, second instar	5 to 14 days;	average,	7.76 days.
Nymph, third instar	7 to 11 days;	average,	8.4 days.
Nymph, fourth instar	8 to 12 days;	average,	9.72 days.
Nymph, fifth instar	9 to 13 days;	average,	11.56 days.
Adult, male	23 to 91 days;	average,	59.5 days.
Adult, female	16 to 95 days;	average,	68.45 days.

11. Newly hatched nymphs do not move far from the place where they hatched. A congregation of different groups of hoppers from different egg-masses compose the swarm.

12. Hoppers select the clear ground where there is shade and where they are exposed to direct sunlight. They pass the night usually on top of grasses and shrubs.

13. Young hoppers do not feed much and consequently do not do much damage. They become markedly destructive as they reach the third stage. More mature hoppers, at times, are able to devour the entire green and soft portions of plants above the surface of the ground.

14. The migratory instincts of hoppers are more evident in about the latter part of the morning and in the early afternoon, during bright days. During cool and cloudy days, however, they are almost always concealed among grass blades and leaves of shrubs or bushes and do not move at all. Newly emerged adults do not migrate at once, but hover first around the region of emergence. During migration, they can travel long distances per day.

15. In the present study, the migratory locust was observed to assume various colorations depending on the immediate environment when confined individually. Green locusts were caught in the fields; these were not found in large groups but often individually. When the progeny of these were grouped together in a cage they lost the green color and attained the migratory color. Whether these correspond to Uvarov's solitary or *danica* phase, cannot as yet be ascertained.

16. The following practical native control measures have long been practiced by the people of these Islands:

a. Digging out the eggs.

b. Pit or driving methods, in which a pit is dug before a swarm of hoppers (only) and these are driven into it and killed. Galvanized iron sheets about 25 centimeters wide are placed vertically at the back of the hole to keep the insect from going beyond the pit. Sheets are also laid in the form of a V with the pit at the vertex and the opening towards the swarm.

c. Netting.

d. Burning.

17. The common yellow Chinese soap when dissolved in water at the rate of 0.4 to 1 kilo of the soap in about 20 liters of water was found effective in killing hoppers in all stages.

18. The following formulæ may also be used against the hoppers:

	Parts
(*a*) Sodium hydrate (98 per cent)	1
Water	12
Resin	6

	Per cent
(*b*) Resin	1.9
Sodium hydrate	0.95
Petroleum	0.7
Water to make	100.0

19. Calcium arsenate dust (25 to 30 per cent in air-slaked lime) at the rate of 5 to 10 kilos per hectare was found effective against both fliers and hoppers. Eighty per cent of the insects were killed at the end of the second day. Ouly 10 per cent were killed at the end of the first day.

20. Poisoned bran bait was also found effective for killing locusts. The following is the formula:

Paris green	kilo	0.9
Rice bran	kilos	22.7
Lemon	do	14.0
Molasses	liters	3.8
Water	do	16.0

During hot weather the molasses may be increased to 4½ liters and the water to 18 liters. From 70 per cent to 85 per cent of the hoppers have been killed at the end of the second day in an experiment.

In the absence of lemon, the rest of the ingredients may still be effective with the following proportions by volume:

Paris green	part	1
Rice bran	parts	50
Molasses	do	5
Water	do	10

21. Locusts are preyed upon by birds, notably the martinez, *Acredotheres cristatellus,* the cabisote, and in populated regions, by the domestic chicken and turkey; reptiles; frogs; and by different species of mammals notably man, the dog, the wild hog, etc.

22. Locusts exhibit a marked degree of cannibalistic instinct, which is more marked during the third and fourth instars.

23. Hairworms (*Gordius*) and mites have been observed on locusts. The presence of the latter, however, seemed to cause the hosts no inconvenience at all and the former were noted in comparatively few locusts, so that they can hardly be considered of importance as enemies.

24. Several specimens have been found dead with a fungus growth on them and some with fungus growing on them while still living. But further tests with this disease failed to give the desired results. The fungus was suspected to belong to the genus Mucor. Two species of fungi, *Empussa gryli* and *Sporotrichum globuliferum,* were reported of great value in killing

swarms of locusts in the United States. These, however, have not yet been encountered in the Philippines, although a white fungus, similar to the latter species was noted to cause death to young hoppers in the laboratory.

25. Coöperation is an important factor in the control of locusts in the Philippines. The Philippine Legislature long ago passed a law compelling every male inhabitant from 16 to 60 years old, inclusive, of an infested region, to exterminate locusts in their respective districts. It also appropriated a yearly sum of ₱100,000 to be used in locust campaigns and in locust research work.

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ILLUSTRATIONS

Plate I

Fig. 1. The egg. ×3½
2. Nymph, first instar. ×2½
3. Nymph, second instar. ×2½.
4. Nymph, third instar. ×2½.
5. Nymph, fourth instar. ×2½.
6. Nymph, fifth instar. ×2½.

Pate II

Development of the nymphal wing-pads.

Fig. 1. First instar.
2. Second instar.
3. Third instar.
4. Fourth instar.
5. Fifth instar.

Plate III

Fig. 1. Adult locust, male, lateral aspect. ~~×1~~ (Slightly reduced)
2. Adult locust, female, lateral aspect. ~~×1~~ (Slightly reduced)
3. Head, anterior view. ×5.
4. Head, ateral view. ×5.
   a, antenna; *c*, clypeus; *e*, compound eye; *f*, front; *g*, gena; *l*, labrum; *lp*, labial palpus; *m*, mandible; *mp*, maxillary palpus; *o*, simple eye or ocellus; *pg*, post-gena; *v*, vertex.
5. Antennae. ×5.
   a, female; *b*, male.
6. Mouth parts of the locust. ×5.
   a. Clypeus and labrum, ectal view.
   b. Hypopharynx, ectal view.
   c. Mandible, ectal view.
   d. Mandible, ectal view.
   e. Left maxilla, ectal view.
   f. Labium, ectal view.
      cd, cardo; *cl*, clypeus; *g*, galea; *gl*, glossa; *l*, lacinia; *lb*, labrum; *lp*, labial palpus; *m*, mentum; *mp*, maxillary palpus; *p*, palpifer; *pg*, palpiger; *pgl*, paraglossa; *s*, stipes; *sg*, subgalea; *sm*, submentum.

Plate IV

Fig. 1. The abdomen of the locust, lateral aspect. ×5.
   c, cercus; *p*, penis; s_1-s_9, abdominal sternites; *sp*, spiracles; t_1-t_{11}, abdominal tergites; *tm*, tympanum.

FIG. 2. Male genitalia, lateral aspect. ×10.
c, cercus; *cx*, coxales; *hy*, hypandrium; *p*, penis; *pg*, pygidium, *sp*, supra-anal plate; 8_t–11_t, abdominal tergites; 8_s–9_s, abdominal sternites.

3. Female genitalia, lateral aspect. ×10.
c, cercus; *dv*, dorsal valves of ovipositor; *iv*, inner valves of ovipositor; *p*, podical plate; *t*, telson; *vv*, ventral valves of ovipositor.

PLATE V

Damage caused by locust fliers on corn.

PLATE VI

Pit or driving method of destroying hoppers.

PLATE VII

A brigade of locust (fliers) fighters.

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PLATE I

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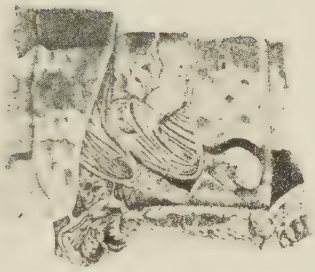

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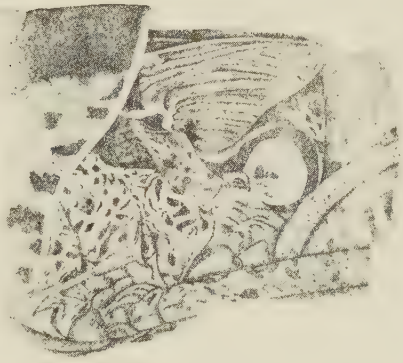

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PLATE II

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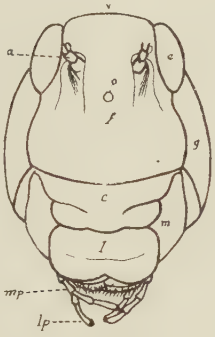

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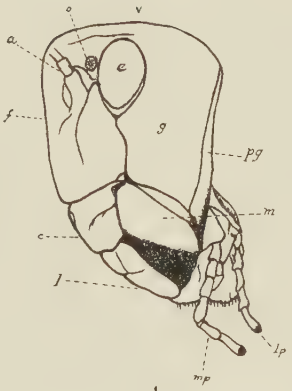

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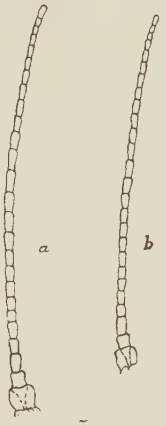

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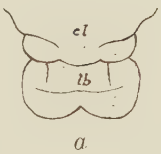

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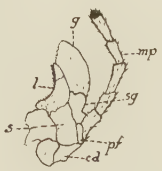

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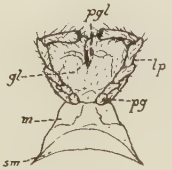

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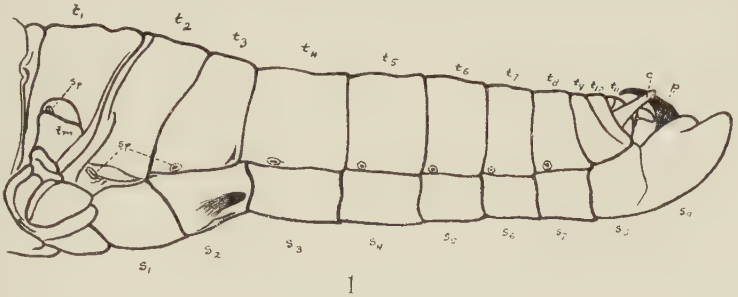
PLATE III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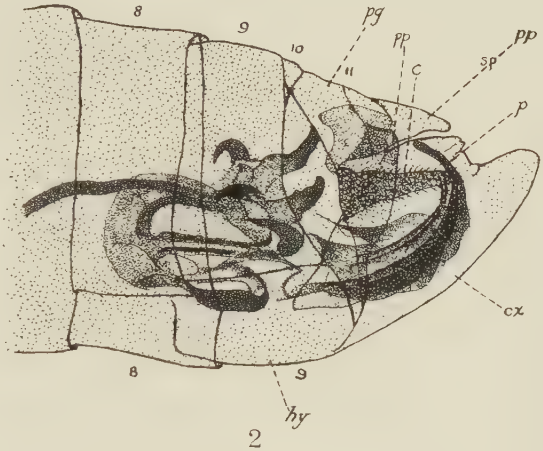
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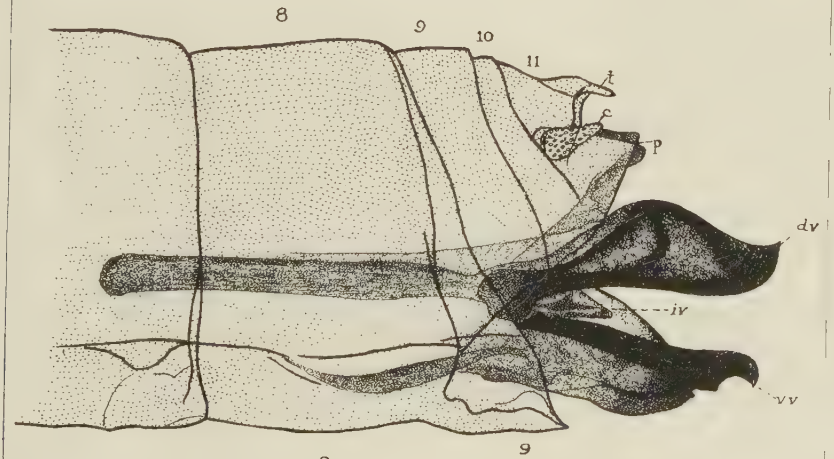
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PLATE IV

PLATE V

PLATE VI

PLATE VII

A PROGRESS REPORT ON POTATO PRODUCTION AS AFFECTED BY DATE OF PLANTING, 1930–1931

By Pedro A. Rodrigo
Of the Bureau of Plant Industry

ONE TEXT FIGURE

That each crop has its preferred season of the year is common knowledge. As to the Irish potato, a comparatively new crop in the Philippines, the best time for its culture here has not yet been definitely ascertained, although it is now generally grown in the Mountain Province from October to February. The variation in the amount of precipitation and its distribution, the relative humidity, and the temperature during the growing period of a crop have a decided influence on its production and on the prevalence of its repressive agencies.

The object of this experiment was to determine the best time to plant Irish potatoes in the Mountain Province, particularly in the Trinidad Valley. The work was conducted at the Baguio Semi-temperate Fruit Experiment Station, Baguio, Mountain Province, and the first trial was started on November 15, 1930, and completed on May 6, 1931.

MATERIALS AND METHODS

In this experiment a fairly level field of practically uniform fertility was used. Plots about 25 square meters each in area (3 by 8.45 meters) were laid out. These were prepared for planting as uniformly as could possibly be done.

The Japanese White potato was the variety used. The cuts were set at 30 centimeters apart in rows spaced at 75 centimeters from each other. Plantings were made on November 15, December 15, 1930, and on January 15 and February 15, 1931. Each planting was replicated nine times. Figures 1 shows the planting plan of the experiment. The treatment of all the seeds and the care of all the plots including cultivation were as uniform as possible.

Field observations were made on the general growth of the plants in the different plantings, and on the prevalence of diseases and insects pests. The crops were harvested as they matured, and the weight of the tubers from the different plot was determined.

RESULTS

The data presented in this report were the results of the trial test made during the planting season of 1930–1931. The yields were comparatively low because the experimental plots were not fertilized.

Field observation.—The shoots began to appear on the surface of the ground from 16 to 18 days after the date of planting, and all were out about a week later.

The potatoes planted November 15 were badly attacked by potato blights, both the early and the late. They were harvested rather prematurely. The December 15, and January 15 plantings although attacked by blights were not so severely injured, and the infection came when the tubers were about half developed. There was also a slight attack by cutworms. The February 15 planting was affected by drought, and while the infection caused by blight was also severe, the stem and root roots seemed to have the edge.

Table 1 shows the effect of the date of planting on the number of days to germination and to maturity. Table 2 gives the actual production of tubers as affected by the date of planting and table 3 is a summary of Table 2. Table 4 shows the quality of the crop as affected by the date of planting. Table 5 presents some weather observations at Baguio taken during the potato growing season of 1930–1931.

TABLE 1.—*Showing the effect of the date of planting on germination and on the maturity of a potato crop*

Date of planting	Germinated		Matured or harvested	
	Date	Days	Date	Days
15–XI–30	2–XII–30	17	5–II –31	82
15–XII–30	2–I –31	18	19–III–31	94
15–I–31	1–II –31	17	13–IV–31	88
15–II–31	3–III –31	16	6–V –31	80

TABLE 2.—*Showing the actual yield of tubers as affected by the date of planting*

Plot number	Date of planting							
	November 15, 1930		December 15, 1930		January 15, 1931		February 15, 1931	
	Actual	Marketable	Actual	Marketable	Actual	Marketable	Actual	Marketable
	Kilos	*Kilos*	*Kilos*	*Kilos*	*Kilos*	*Kilos*	*Kilos*	*Kilos*
1	3.4	2.6	9.8	9.2	7.8	7.4	5.2	4.3
2	4.0	2.9	9.5	9.0	7.1	6.7	2.2	1.7
3	3.5	2.3	9.4	9.0	6.1	5.7	2.7	2.3
4	3.7	2.4	8.7	5.3	11.2	10.8	4.1	3.3
5	3.0	2.3	9.7	9.1	4.0	4.3	4.5	3.9
6	1.8	1.1	5.3	5.0	3.9	3.6	3.0	2.5
7	1.1	0.7	8.9	8.3	7.2	6.9	5.1	4.5
8	1.3	0.9	5.0	4.6	4.2	3.9	4.9	4.1
9	2.1	1.4	5.4	5.0	5.9	5.7	5.8	4.9
Average	2.66	1.84	7.97	7.50	6.44	6.10	4.17	3.50
P. E.	±0.23	±0.27	±0.44	±0.42	±0.48	±0.46	±0.26	±0.23

TABLE 3.—*Showing the average yield per plot as affected by the date of planting*

Date of planting	Area of plot	Average total yield		
		Weight	Difference	Significance
	Sq. m.	*Kilos*	*Kilos*	
15–XI–30	25	2.66±0.23		
15–XII–30	25	7.97±0.44	5.31±0.50	Significant.
15–I–31	25	6.44±0.48	1.53±0.65	Insignificant.
15–II–31	25	4.17±0.26	2.27±0.55	Significant.

Date of planting	Area of plot	Marketable tubers		
		Weight	Difference	Significance
	Sq. m.	*Kilos*	*Kilos*	
15–XI–30	25	1.84±0.17		
15–XII–30	25	7.50±0.42	5.66±0.45	Significant.
15–I–31	25	6.10±0.46	1.40±0.62	Insignificant.
15–II–31	25	3.50±0.23	2.60±0.51	Significant.

TABLE 4.—*Showing the quality of tubers as affected by the date of planting*

Date of planting	Average yield per plot	Marketable tubers		Cull	
		Kilos	Per cent	Kilos	Per cent
	Kilos				
15–XI–30	2.66	1.84	69.55	0.82	30.45
15–XII–30	7.97	7.50	94.10	0.47	5.90
15–I–31	6.44	6.10	94.72	0.34	5.28
15–II–31	4.17	3.50	84.34	0.67	15.66

TABLE 5.—*Showing some weather data at Baguio during the potato growing season, 1930–1931* [a]

Month	Number of rainy days	Monthly rainfall	Average temperature	Average relative humidity
1930		*mm.*	*°C.*	*Per cent.*
October	17	188.2	18.4	87.4
November	6	14.7	17.7	81.6
December	15	108.9	17.2	88.0
1931				
January	5	7.9	16.9	81.5
February	0	0.0	17.0	76.1
March	1	1.7	18.0	79.1
April	4	6.1	19.2	78.8

[a] Data taken from the Weather Observatory, Mt. Mirador, Baguio.

DISCUSSION OF RESULTS

The date of planting had practically no effect on the number of days it took the seed to germinate. As a rule, the shoots began to come out of the soil in from 16 to 18 days after planting.

The potato crop did not mature properly from any planting. This was particularly so with the November 15 and February 15 plantings, especially in the case of the former. In the November 15 planting, potato blights appeared early, which consequently prevented a great number of the tubers from attaining even as fair size. In the case of the December 15 and January 15 plantings, the blights appeared quite late in the growing period of the plants, thus allowing a great percentage of the tubers to attain a marketable size, but they were not able to mature properly. The November 15, planting was harvested 82 days after planting; the December 15 planting, 94 days; the January 15 planting, 88 days; and the February 15 planting was harvested 80 days after planting (see Table 1). Practically all the plants were dead when the crops of the November 15 and February 15 plantings were harvested.

Effect of date of planting on yield.—As seen in tables 2 and 3 the total yield as well as the marketable tubers per plot were greatly affected by the date of planting. The December 15 planting gave the highest yield in both the total and the marketable tubers, and the January 15 planting was a close second. The February 15 planting gave the third highest yield in both the total and marketable tubers, and the November 15 planting gave the poorest yield.

The November 15 planting gave an average total yield of 2.68 ± 0.23 kilos and 1.84 ± 0.17 kilos of marketable tubers for every 25 square meter-plot, while the December 15 planting gave an average total yield of 7.97 ± 0.44 kilos and 7.50 ± 0.42 kilos of marketable tubers, giving an increase of 5.29 ± 0.50 kilos in the average total yield and 5.66 ± 0.45 kilos in the average marketable tubers. These increases are considered decidely significant. The January 15 planting, which was second highest in yield, gave an average total yield of 6.44 ± 0.48 kilos and 6.10 ± 0.46 kilos of marketable tubers. While the December 15 planting gave a slightly higher yield both in the average total and in the average marketable tubers than the January 15 planting, the difference in yield as interpreted in the light of the probable error concept, is not considered significant. The January 15 planting, however, was decidedly better than the November 15 planting and the February 15 planting. The February 15 planting gave an average total yield of 4.17 ± 0.26 kilos and 3.50 ± 0.23 kilos of marketable tubers. It gave a decided increase in yield in both the average total and the marketable tubers over the November 15 planting.

It should be remarked in this connection that the difference in yields were mainly due to the severe attack of potato blight which prevented the proper maturity of the tubers; many of the tubers, especially from the November 15 and February 15 plantings, attained a diameter of from 1.0 to 1.5 centimeters. As seen in table 4, 30.45 per cent of the yield of the November 15 planting was classified as cull; 15.66 per cent of the February 15 planting; while the per cent cull was 5.90 and 5.28, respectively, for those of the December 15 and January 15 plantings. The tubers which were classified as cull were small and immature due to the premature dying of the plants.

The date of planting had a great deal to do with the prevalence of potato diseases. In the November 15 planting, the potato blights were observed about two weeks after germination, while in the December 15 and January 15 plantings, these potato disease were not observed until the tubers were fairly well advanced in their development. The stem and root rots seemed to get worse as the soil became drier.

The rainfall, the number of rainy days per month and the average relative humidity seemed to be the climatic factors

which affected or influenced the prevalence of the disease. The rainfall, the number of rainy days, and the average relative humidity during December, 1930 were comparatively very much higher as compared with those of January to April, 1931 (see Table 5). The rains in December, 1930, greatly affected the early growth of the potato planted on the fifteenth of the previous month (November). It appears evident that the variation in the climate conditions during the time limit of this experiment greatly affected the prevalence of potato diseases which ultimately affected the stand and the production of the crop. In early plantings, better crops may be obtained by the judicious use of Bordeaux mixture spray, and in late plantings, the stand of a crop may be improved by irrigation.

SUMMARY AND CONCLUSIONS

From the limited data presented in this report the following conclusions may be justified:

1. The date of planting had practically no effect on the number of days it took the potato seed to germinate. The number of days to germination ranged from 16 to 18 days.

2. The potato crop did not mature properly because of potato blights. This was more pronounced with the November 15 plantings; the February 15 planting was further affected by drought.

3. The prevalence of potato blights was more or less correlated with the amount of rainfall, the number of rainy days, and the average relative humidity during the early growing period of the plant. Because of more rain in the month of December, 1930, the November 15 planting was badly attacked by potato blights.

4. The December 15 and January 15 plantings gave the highest yields, with 3,183 and 2,576 kilos per hectare respectively. The February 15 and November 15 planting gave 1,668 and 1.072 kilos per hectare, respectively.

5. The December 15 and January 15 crops further gave the highest marketable tubers, 94.0 per cent and 94.7 per cent of the crops, respectively, being marketable. Of the November 15 crop, 69.5 per cent was marketable, while 84.3 per cent of the February crop was also classified as marketable.

This experiment should be carried on through a series of years, so as to definitely ascertain the best time to plant seed potatoes in the Mountain Province. Also, in this connection,

fungicide and insecticide experiments should be conducted to determine their efficacy, with the ultimate aim in view of widening the range in which potatoes can be grown commercially in the Mountain Province.

1	2	3	4	1	2	3	4	1
2	3	4	1	2	3	4	1	2
3	4	1	2	3	4	1	2	3
4	1	2	3	4	1	2	3	4

FIG. 1. Method of arranging the plots. Plots No. 1 were planted November 15, 1930; Plot No. 2, December 15, 1930; Plot No 3, Jaunary 15, 1931; and Plot No. 4, February 15, 1931.

ILLUSTRATIONS

FIG. 1. Method of arranging the plots. Plots No. 1 were planted November 15, 1930; Plot No. 2, December 15, 1930; Plot No. 3, January 15, 1931; and Plot No. 4, February 15, 1931.

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A PROGRESS REPORT ON THE EFFECT OF COMMERCIAL FERTILIZERS ON IRISH POTATO PRODUCTION IN BAGUIO, 1930–1931

By PEDRO A. RODRIGO
Of the Bureau of Plant Industry

ONE TEXT FIGURE

The growing of Irish potatoes, *Solanum tuberosum* L., in the Mountain Province, particularly in the Trinidad Valley, is bound to be one of the main branches of the now famous vegetable industry in this section of the country. The intensive cropping practice, together with the well known rapidity with which soils in the region get impoverished because of soil erosion are problems intimately connected with potato growing that are of primary concern.

The writer is not aware of any fertilizer experiments on potatoes ever conducted in the Philippines. Potato growers in the Mountain Province, however, use fertilizers quite freely, but they generally do it without much regard to the expense incurred and the amount and kind of fertilizers applied.

Fertilizer experiments on potatoes in the United States have shown that the kind of fertilizer, its amount and composition need to be governed by the type of soil, its fertility, the crop sequence adapted, the climatic conditions prevailing, and some minor factors. In Virginia,[1] for example, a fertilizer with 5–8–5 formula at the rate of 800 to 1,000 pounds per acre (899 to 1,682 kilos per hectare) is recommended for commercial planting, while in Missouri,[2] one with 4–12–4 formula applied at the rate of 500 pounds to the acre (561 kilos per hectare) in combination with barnyard manure gave the highest yield of No. 1 potatoes. On the other hand, a recent test in Wisconsin[3] showed that a

[1] Hutcheson, T. B. and T. K. Wolfe. Potato Culture. Vir. Agric. Expt. Station Bulletin No. 217:1–16. 1917.

[2] Talbert, T. J. and J. T. Quinn. Cultural Experiments with Irish Potatoes. Experiment Station Research. Mo. Agric. Expt. Sta. Bulletin No. 285: p. 85.

[3] Anonymous. Highly concentrated fertilizers show profit with potatoes. New Science for and Old Art (Annual Report of the Director, 1928–1929). Wis. Agric. Expt. Station Bulletin No. 410:8–10.

highly concentrated commercial fertilizer (10–16–14) at the rate of 400 pounds per acre (449 kilos per hectare) was very much more economical for potatoes than a less concentrated one (5–8–7) at the rate of 800 pounds per acre (899 kilos per hectare). The average production from the two rates of application were about the same, but the cost of the fertilizers and their application was very much less in the former case. In this connection, it should be borne in mind that whenever concentrated fertilizers are used, they should be well mixed with the soil and should not come in close contact with the seed lest some fertilizer injury may occur.

It was the object of this study to determine the best amount of a complete fertilizer (9–12–9) to be added to the soil for the most profitable production of potatoes under Baguio conditions. Incidentally, the effect of the different amounts of fertilizers on the severity of potato diseases was observed.

This study was conducted at the Baguio Semi-temperate Fruit Experiment Station, Baguio, Mountain Province. The first trial was started in December, 1930, and completed March 15, 1931.

MATERIALS AND METHODS

For this experiment, a level field of 1,000 square meters was used. The field was divided into forty rectangular plots with an area of 25 square meters each. The laying out of the plots was made after the field had been uniformly and thoroughly prepared. The fertilizer used was complete, having a formula of 9–12–9; it contained 9 per cent nintrogen from ammonium sulphate, 12 per cent phosphoric acid from superphosphate, and 9 per cent potash from sulphate of potash. The fertilizers were compounded in the Station, and were thoroughly mixed before they were applied.

The fertilizers were applied in furrows. They were thoroughly worked into the soil before the seed potatoes were set in.

Three rates of application were employed: 200, 450, and 700 kilos per hectare. Check plots (without fertilizer) were also run side by side with the fertilizer plots. Each treatment was replicated ten times. The method of arranging the plots is shown in Fig. 1.

The Japanese White potato was used in this experiment. The seed was directly imported from Japan through a local Japanese dealer. The tubers were cut to a more or less uniform size with two or more eyes per cut. These were planted at 25 centi-

meters in furrows opened at one meter apart. The depth of planting was about from 5 to 1 centimeters. The different plots were weeded, cultivated, and watered as uniformly as could possibly be done, and as necessity demanded.

Field observations were made on the general growth of the plants, and on the prevalence of insect pests and fungus diseases. At harvest time, the different plots were harvested separately. The harvest from each plot was sorted into marketable and unmarketable tubers, and then weight and recorded accordingly.

RESULTS

The data presented in this report were the results of the fertilizer test conducted in 1930–1931.

Field observations.—The seed germinated at practically the same time. Soon after germination, the effect of the fertilizers became evident. The plants in the fertilized plots at the rate of 450 and 700 kilos per hectare were vigorous and dark green in color. The young plants had thick and sturdy shoots. As the soil became drier, however, some fertilizer injury to the plants became noticeable (this became evident when the turbers were about from 2 to 3 centimeters in diameter). The fertilizer injury was more apparent with the heavier applications.

Table 1 shows the actual yields, both total and marketable turbers, of the different rates of applications, and table 2 is summary of table 1. Table 3 gives the computed yield per hectare. Table 4 presents the computed gains of the different rates of application over the unfertilized plots, and table 5 shows the effect of the fertilizers on the percentage of cull.

TABLE 1.—*Showing the actual yield of potato as affected by the amount of fertilizer (9–12–9) applied*

Plot number	Rate of application per hectare							
	Check		200 kilos		450 kilos		700 kilos	
	Actual	Marketable	Actual	Marketable	Actual	Marketable	Actual	Marketable
	Kg.	*Kg.*	*Kg.*	*Kg.*	*Kg.*	*Kg.*	*Kg.*	*Kg.*
1	5.9	5.3	6.5	5.4	9.4	8.0	13.3	11.4
2	6.7	5.8	8.0	7.2	8.1	7.1	9.4	7.9
3	4.5	3.8	8.0	6.5	15.1	13.7	14.7	13.2
4	4.1	3.4	5.6	4.6	8.0	6.6	8.7	7.2
5	9.0	5.1	11.1	9.8	11.0	9.8	9.2	7.6
6	4.0	3.8	8.6	7.8	7.6	6.6	8.3	7.3
7	8.3	7.4	8.1	7.1	8.6	7.1	11.9	10.9
8	3.5	2.8	6.9	6.0	14.6	13.2	14.1	12.8
9	6.6	5.8	7.0	6.2	10.7	9.3	12.0	10.6
10	7.8	7.2	8.2	6.9	12.1	10.9	12.4	11.1
Average	6.04	5.34	7.80	6.75	10.52	9.23	11.40	10.00
P. E.	±0.40	±0.37	±0.30	±0.29	±0.55	±0.54	±0.47	±0.46

TABLE 2.—*Showing the effect of different amounts of fertilizers on the production of potato (25-square-meter plot)*

Rate of application per hectare	Average total yield per plot	Difference	Significance of difference	Average marketable tubers per plot	Difference	Significance of difference
Kilos	*Kilos*	*Kilos*		*Kilos*	*Kilos*	
Check	6.04±0.39			5.34±0.37		
200	7.80±0.30	1.76±0.49	Significant	6.75±0.29	1.41±0.46	Significant.
450	10.52±0.55	2.72±0.63	Significant	0.23±0.54	2.48±0.61	Significant.
700	11.40±0.47	0.88±0.73	Insignificant	10.00±0.46	0.77±0.71	Insignificant.

TABLE 3.—*Showing the average relative yields per hectare as affected by the rate of application of fertilizer*

Rate of application per hectare	Yield		Marketable tuber	
	Total	Relative	Total	Relative
Kilos	*Kilos*	*Per cent.*	*Kilos*	*Per cent.*
Check	2,416	100	2,136	100
200	3,120	129	2,700	126
450	4,208	174	3,692	173
700	4,560	189	4,000	187

TABLE 4.—*Showing the gains of the fertilized plots over the unfertilized ones—hectare basis*

Rate of application per hectare	Cost of fertilizer per hectare	Marketable tubers	Increase in yield	Value of increase[1]	Gain over check
Kilos	*Pesos*	*Kilos*	*Kilos*	*Pesos*	*Pesos*
Check		2,136			
200	24.56	2,700	564	84.00	60.04
450	55.56	3,692	1,556	233.40	178.14
700	85.97	4,000	1,864	279.60	193.63

[1] Based upon Baguio wholesale price. One kilo of ungraded marketable tubers costs, in the average, 15 centavos.

TABLE 5.—*Showing the effect of different amounts of fertilizer on the percentage of culls*

Rate of application per hectare	Average actual yield per plot	Average cull per plot		Relative yield of marketable tubers
		Weight	Per cent	
Kilos	*Kilos*	*Kilos*		*Per cent*
Check	6.04	0.70	1.17	100
200	7.80	1.05	13.46	126
450	10.52	1.29	12.26	173
700	11.40	1.40	12.28	187

DISCUSSION OF RESULTS

The effect of fertilizer on growth.—The different rates of application of the fertilizer used did not have any effect on the number of days it took the seed to germinate. The unfertilized and fertilized plots germinated at practically the same time.

But soon after germination, there was a decided response of the plants to the fertilizers used. In the fertilized plots, the plants became green and vigorous in growth, and the shoots were thick and sturdy as compared with those in the unfertilized plot.

The rather dry condition of the soil when the tubers were about 2 cm. in diameter had some bad effect on the fertilized plots, particularly with the heavier applications. This is to be expected when rather heavy applications are made if the soil is quite dry and when the fertilizers are applied close to the plants. Because of this apparent weakened condition of the plants in these plots, the attack of potato blight seemed to have been more severe. Such fertilizer injury, however, may be prevented by a better incorporation of the fertilizers in the soil before planting. Instead of putting the fertilizers in the furrows as was done in this study, they should be broadcasted all over the field just before the last plowing is done so as to mix the fertilizer with the soil more thoroughly.

The effect of fertilizer on production.—As seen in tables 1 and 2, the fertilized plots gave greater average yields than the check plots. The increase in production was more or less proportional to the amount of fertilizer applied. The check gave an average total yield of 6.04 ± 0.39 kilos and 5.34 ± 0.37 kilos of marketable tubers. On the other hand, the plots fertilized at the rate of 200 kilos per hectare gave an average total yield of 7.80 ± 0.30 kilos and 6.75 ± 0.29 kilos of marketable tubers, giving an increase over the check of 1.76 ± 0.49 kilos in average total yield, and 1.41 ± 0.46 kilos in marketable tubers. These increases, interpreted in the probable error concept, are considered significant. The plots with the 450-kilos rate per hectare gave an average total yield of 10.52 ± 0.55 kilos and 9.23 ± 0.54 kilos of marketable tubers, giving an increase of 2.72 ± 0.63 kilos in total yield, and 2.48 ± 0.61 kilos in marketable tubers over the 200-kilo application. These increase too are very significant. For the plots with 700-kilo rate per hectare, the average total yield was 11.40 ± 0.47 kilos with 10.00 ± 0.46 kilos as marketable tubers. These gave an increase of 0.88 ± 0.73 kilos in average total yield of 0.77 ± 0.71 kilos in marketable tubers over the plots fertilized at the rate of 450 kilos per hectare. While these increases are not considered significant, their money value as seen in tables 4 is something to be reckoned with.

For a better appreciation by the general public on the significance of the results of this study, Tables 3 and 4 were prepared.

As seen in table 3 on the columns of relative yields, the increases in total production of the plots treated at the rate of 200, 450, and 700 kilos per hectare were 29, 73, and 89 per cent, respectively, and 26, 73, and 87 per cent respectively, on marketable tubers. In table 4, it is further shown that it pays to fertilize potatoes. The 200-kilo rate per hectare gave a net gain of ₱60.04 per hectare over the check; the 450-kilo rate, ₱178.14; and the 700-kilo rate, ₱193.63.

In Table 5, it is seen that the fertilized plots had the tendency to promote a greater percentage of cull in the yield. This rather high percentage of unmarketable tubers however, might have been due to the improper maturity of the crop, as previously stated, because of some fertilizer injury and because of the more severe attack of fungus diseases.

SUMMARY AND CONCLUSIONS

From the results presented in this report, the following conclusions may be drawn:

1. The fertilizer applied at different rates had no effect on the germination of potato seed.

2. The application of 450 and 700 kilos of fertilizer per hectare favored the vigorous growth of the potato plants.

3. Because of the rather dry condition of the soil during the development of the tubers, some fertilizer injury was observed in the plots fertilized at the rate of 450 and 700 kilos per hectare. Also, the attack of potato blights seemed to have been more severe in these plots.

4. The 700-kilo rate per hectare was the best application, and the 450-kilo rate was the second best. The increases in yield of marketable tubers over the check plots were 26 per cent for the plots fertilized at the rate of 200 kilos per hectare; 73 per cent for those treated at the rate of 450 kilos; and 87 per cent for those fertilized at the rate of 700 kilos to the hectare.

5. The net gains brought about by the use of fertilizer were ₱60, ₱178, and ₱194 per hectare for the 200-, 450-, and 700-kilo rate, respectively.

6. The fertilized plots showed a tendency to produce a greater percentage of unmarketable tubers. This tendency, however, might have been due to the improper maturity of the crop due to some fertilizer injury.

It is suggested that this study be carried through a series of years so as to obtain more reliable data. Also, the use of fertilizers of higher concentration is worth including in this test as

such kinds have been found to be more economical in certain sections in the United States than less concentrated ones.

1	2	3	4	1	2	3	4	1	2
3	4	1	2	3	4	1	2	3	4
1	2	3	4	1	2	3	4	1	2
3	4	1	2	3	4	1	2	3	4

FIG. 1. Method of arranging the fertilizer plots. Plots No. 1 did not receive any fertilizer (check); Plots No. 2, fertilized at the rate of 200 kilos per hectare; Plots No. 3 at the rate of 450 kilos per hectare; and Plots No. 4, at the rate of 700 kilos.

ILLUSTRATIONS

FIG. 1. Method of arranging the fertilizer plots. Plots No. 1 did not receive any fertilizer (check); Plots No. 2, fertilized at the rate of 200 kilos per hectare; Plots No. 3, at the rate of 450 kilos per hectare; and Plots No. 4, at the rate of 700 kilos. 57

ON THE GROWTH OF COCONUT ROOTS [1]

By VICENTE C. ALDABA
Of the Bureau of Plant Industry, Manila

SIX PLATES

INTRODUCTION

In the Philippines at present there are over 105,000,000 coconut trees planted covering an area of over 500,000 hectares. A person going through the coconut plantations, especially those about 15 years of age or older can very often see a tree with the upper part of the root system entirely exposed. (Plates I-IV.) This is mainly due to the erosion of the soil caused by the heavy tropical rains. The roots become stunted and fail to reach the ground. As far as the tree is concerned they are entirely useless. But if these roots could be made to grow, the tree would have many more roots with which to obtain the necessary food elements from the ground. Moreover, there would be more roots to hold the tree firm, and this is of especially great import during typhoons.

As a matter of general observation, productivity of a plant is correlated with the development of the roots system. Physiologically this should be so, since high productivity is possible only when there is ample provisions for facilities to obtain plant food materials from the ground. The roots [1] of corn have been found to increase in number continously until the plant is mature. In the case of sugar cane, Wolters [2] summarizes the findings of a number of investigators by stating "that it appears to be a definite conclusion that heavy root weights are correlated with heavy cane tonnage," and Roxas and Villano [3] found in their experiments in the Philippines that increased shoot development corresponded to increase root development, without exception. Sampson [4] in his investigation of coconut productivity found that regular bearing trees showed better developed root systems than irregular bearing ones.

[1] The experiments described in this paper were performed in a private plantation in Los Baños when the writer was connected with the College of Agriculture and has charge of the works on ~~account~~ coconut and other oil plants.

THE PROBLEM

Here, then, is a problem the solution of which would certainly result in tremendous benefit to the country considering that there are more than 105,000,000 coconut trees in the Philippines.

These trees are in all stages of growth and in all conditions of health. In many cases they bear scarcely any nuts and have a very anemic appearance because the root systems are not sufficiently developed to meet the requirements of a healthy productive tree adequately. It should be stated in this connection that new coconut roots are produced above the older ones in the bole. After a certain age the oldest roots die. New roots to take the place of those that die must develop. If on account of exposure to the air the new roots fail to reach the ground, then the tree will have to depend solely on the roots already present, which naturally diminish in number as the old ones die.

EXPERIMENTS AND RESULTS

It seems that by covering these roots with soil or other materials they may continue to grow. The exposed roots of a coconut tree therefore, have been covered with soil in February, 1927 (Plate I). In November, 1927, part of the soil covering was removed. It was found that the roots which otherwise would have become dormant and of no use to the tree, had grown rapidly and luxuriantly as graphically shown in Plate II. In September, 1928, the same part of the root system was uncovered and they showed still more luxuriant growth (Plate III).

The growing of the individual coconut roots is very well shown in figure 6. The dormant roots when covered by soil do not continue to grow but instead they produce branches of almost the same size a little behind the tip.

The covering of the exposed roots by soil in many cases may not be practicable except when the owner has only a few trees. When it comes to plantations of big areas, covering the exposed roots with soil becomes difficult, and in many cases would be unprofitable because of the labor involved.

Considering, however, the present cultural practice in the Islands there is another material, the coconut husk, which may readily be used and which is now either burned or just allowed to rot. At present in order to save in transportation the practice in many places consists in husking the nuts right in the place where they are gathered, taking only the husked nuts to the drying sheds or to more distant places for sale. The husks are piled between the trees and burned. This is done after every harvest-

ing which takes place from 3 to 4 times a year. If instead of doing this the husks were piled at the bases of the coconut trees to cover the exposed roots, no extra expense would be incurred. At the same time a tremendous benefit would accrue to the trees, for it stands to reason that the husks piled around the bases of the trees would have practically the same influence on the growth of the dormant roots as a soil covering.

In Plate IV is shown a coconut tree which was photographed in February, 1927. In Plate V is shown the same tree, photographed in November, 1927, that is 9 months after the exposed roots were covered with coconut husks. The roots as may be seen, have grown into the ground thereby becoming useful to the tree.

DISCUSSION

There are enough husks wasted to cover the roots of all the coconut trees completely all the time. Taking the average production per tree all over the Islands which was 33 in 1929, certainly in 3 years of this practice, the bases of the coconut trees should be so completely covered that the roots should develop as luxuriantly as when it is covered by soil. No extra work was spent in doing this and the benefit to the industry in the form of greater productivity of the individual trees would be incalculable, remembering again that there are at present over 105,000,000 coconut trees.

There is, however, a problem in connection with such disposition of the husks. The old practice of burning the husks is evidently due to the idea that when left decaying in the ground they may serve as breeding places for coconut beetles. This however, had been found not to be true. As shown by well controlled investigation the coconut beetles do not breed in piles of coconut husks.[5]

SUMMARY AND CONCLUSION

1. On account of the erosion of the soil due to the heavy tropical rains, a large part of the root system of the coconut trees in the Philippines become exposed in due time and the new roots fail to reach the ground. They are thus entirely useless to the trees.

2. Experiments have shown that by covering the exposed roots with soil or coconut husks they continue to grow into the ground and thus become useful to the coconut tree.

3. On physiological grounds and in the light of the results of investigations on coconuts and other plants it is concluded that

when these exposed roots reach the ground, thus giving them a chance to be of service to the tree, greater productivity should result.

4. Considering the present cultural practice, the exposed part of the root system may be adequately covered to stimulate the growth of the stunted roots into the ground without extra expense by piling husks around the hole of the trees instead of between the rows to be burned or to be allowed to rot.

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ILLUSTRATIONS

PLATE I. A coconut tree showing the exposed roots as a result mainly of soil erosion. The younger roots, which naturally develop above the older ones, become stunted and do not reach the ground.

II. The same coconut tree as shown in Plate I, nine months after the exposed roots were covered with soil. The roots have grown rapidly and luxuriantly.

III. The same coconut tree, twenty months after the exposed roots were covered with soil. More roots have developed.

IV. A coconut tree showing the exposed roots as a result mainly of soil erosion.

V. The same coconut tree as shown in Plate IV, nine months after the exposed roots were covered with coconut husks.

VI. Shows how growth is resumed by producing branches after the roots which are exposed and stunted are covered by soil and husks.

PLATE I. A coconut tree showing the exposed roots as a result mainly of soil erosion. The younger roots which naturally develop above the older ones, become stunted and do not reach the ground.

PLATE II. The same coconut tree as shown in Plate I, nine months after the exposed roots were covered with soil. More roots have grown rapidly and luxuriantly.

PLATE III. The same coconut tree as shown in Plate I, twenty months after the exposed roots were covered with soil. More roots have developed.

PLATE IV. A coconut tree showing the exposed roots as a result mainly of soil erosion.

PLATE V. The same coconut tree as shown in Plate IV, nine months after the exposed roots were covered with coconut husks.

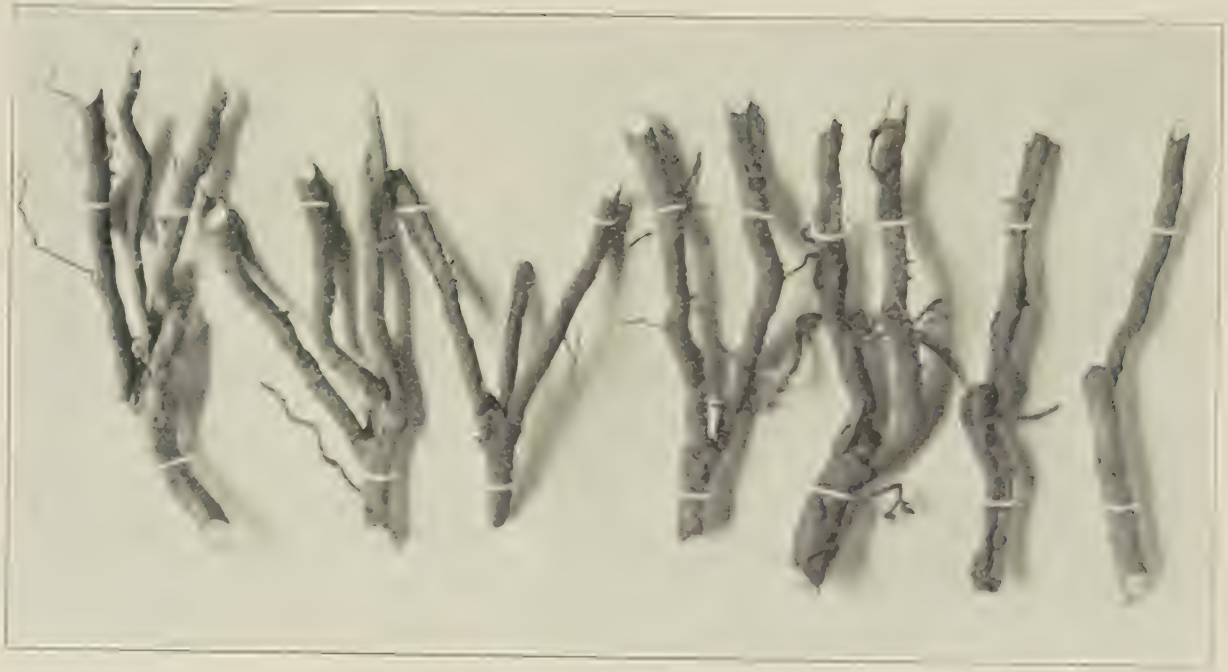

PLATE VI. Shows how growth is resumed by producing branches after the roots which are exposed and stunted are covered by soil or husks.

ARROWROOT (*MARANTHA ARUDINACEA L.*); ITS POSSIBILITIES IN THE PHILIPPINES

By TORIBIO VIBAR
Of the Bureau of Plant Industry

and

ZOSIMO MONTEMAYOR
Of the Bureau of Education

TWO PLATES

1. COMMERCIAL IMPORTANCE

Arrowroot is generally known in the Philippines as "aroro," "aloro," and "uraro." From the root-stocks of this plant comes the arrowroot starch of commerce. These root-stocks may be boiled and eaten before they become too old. Because of its easy digestibility, arrowroot starch is of special value as food for children, convalescents and invalids. Delicious pudding is made of arrowroot starch. This starch makes an excellent component of the common arrow-root biscuits made in Laguna, which sell at about ₱0.60 per 100. Arrowroot biscuit-making is a well developed home industry in the town of Lilio in this province. Wheat-flour biscuits and cookies are very much improved by the addition of some arrowroot starch. Because of its amenability to field culture on a large scale, and because of its superior qualities for biscuits, cookies, and other food preparations, arrowroot is among those economic plants adapted to conditions in the Philippines that have great agricultural and commercial possibilities.

2. CLIMATIC REQUIREMENTS

Arrowroot does best where the rainfall is uniformly distributed throughout the year, or in those places where the dry season is of short duration, but it will thrive anywhere in the Philippines where the water requirements of the plant are satisfactory. The climatic conditions in the eastern half of the Philippine Islands or in those places more or less subject to the current that brings moisture to the Islands from the Pacific Ocean are well suited to the culture of arrowroot. A sufficient water supply in the soil throughout the growing period of the

plant is of primary importance. Generally arrowroot in the Philippines is grown only on a small scale in the yards and along the fences close to houses. The plant grows under partial shade. It is interplanted with coconuts and bananas. It is also adapted to open field culture. It grows from sea level to an elevation of a few thousand feet above the sea. Provided the soil is good, arrowroot can stand adverse weather conditions. As the plants grow to a height of about three feet only, it is not seriously injured by strong winds.

3. SOIL REQUIREMENTS

Arrowroot requires friable well drained loam soil. Soils that do not drain well are not well suited to the culture of this plant because the rhizomes are likely to rot. Hard clay soils are also not good because the rhizomes in this kind of soil cannot develop well; and in harvesting, many of them get broken, soiled and spoiled. Soils at the foot of hills, soils in valleys, alluvial soils, and soils in newly opened lands are good for arrowroot culture. Production depends largely on soil condition and fertility. Worn-out old soils intended for arrowroot cultivation should receive a liberal dressing of manure or commercial fertilizers. The soil should be plowed deep and pulverized thoroughly before planting.

4. PROPAGATION

Arrowroot is propagated by suckers. Suckers in great number develop around the mother plant. (See Plate I.) These suckers are easily detached. The leaves should be cut off, and the suckers should be planted before they dry out. If the supply of suckers is not sufficient, rhizomes can also be used for planting. To insure the supply of planting materials, it is advisable to make nursery planting of suckers, or rhizomes, or both. The suckers can be separated as often as they are old enough and when necessary in order to secure enough planting materials.

5. PLANTING

Arrowroot may be planted any time of the year provided the soil contains enough moisture. The best time for planting, however, is in May and June at the beginning of the rainy season. The moisture-temperature condition of the soil at this time of the year is very favorable to the development of the plant. Arrowroot is usually planted in hills or ridges like camotes.

Two or three suckers are planted to the hill, the hills are one meter and the plants in the row 75 centimeters apart. This distance of planting facilitates weeding and cultivation. Closer plantings may be made. If the soil is relatively poor the rows may be spaced 75 centimeters and the plants in the row 30 centimeters. As much water is needed in the extraction of starch, arrowroot should be planted near streams. Planting made in Los Baños using different numbers of suckers to the hill gave the following production:

TABLE 1.—*Effect of rate of planting on the production of arrowroot rhizomes*

Suckers per hill	Distance of planting	Yield per hill	Yield per hectare (computed)
Number	*Meters*	*Kilograms*	*Kilograms*
1	1×.75	2.76+.0498	36,932.41
2	1×.75	2.99+.0449	39,865.67
3	1×.73	3.17+.0634	42,265.61

6. CARE OF THE CROP

Early planting or planting soon after the first rains in May will give the plant time to develop before the heavy rains set in, and cover the ground, thus reducing the cost of weeding. Efforts should be made to control weeds and to keep the soil well cultivated during the first three or four months, after which but little care will be needed because the plants will then be well established. Flowers appearing before harvesting time should be cut off in order that the energy of the plant may be conserved for the production of rhizomes.

7. HARVESTING

Arrowroot is ready for harvest in elevent to twelve months from the time of planting. Flowers appear at about this time, and the leaves dry up when the weather is warm, showing maturity. No difficulty will be encountered in harvesting if the soil is friable. The plants can be pulled up after the soil around them is loosened with a hoe or other garden tool. If the soil is rather hard, breakage of the rhizomes can be minimized by digging up the soil around the plant close to therhizomes. Spading or forking up the rhizomes, then, is greatly facilitated.

Arrowroot trials made at Los Baños on the yield of rhizomes and starch from different ages gave the following results:

TABLE 2.—*Yield of rhizomes and starch of arrowroot harvested at different ages*

Age		Yield per hill	Computed yield of rhizomes per hectare	Starch	Computed yield of starch per hectare
Months	*Days*	*Kilograms*	*Kilograms*	*Per cent*	*Kilograms*
8	8	.47+.00565	4.700	10.00	488.80
9	9	1.27+.01030	12.750	15.90	2,027.25
10	10	1.60+.02910	16.000	13.40	2,144.00
11	8	2.70+.05630	27.000	15.60	4,212.00
12	1	2.89+.07530	28.900	15.35	4,436.15

Arrowroot rhizomes have a much better and longer keeping quality than cassava roots. Cassava roots spoil in a few days after harvesting especially if they are cut or bruised. The arrowroot rhizomes can be kept for two or three weeks if they are free from injury and if they are not washed. But injured arrowroot rhizomes are subject to all kinds of rots, among which is *diplodia*. Better and longer keeping quality is a great advance for it gives more time for gathering the roots and the extraction of starch. If extraction is delayed the rhizomes should be kept dry in a well ventilated place.

8. EXTRACTION OF STARCH

After being dug up, the rhizomes are gathered and the unsound ones that might likely lower the quality of starch are sorted out. The sound rhizomes are washed thoroughly. Then they are pounded in mortars, or crushed in rollers to reduce them to pulp. A better quality of starch is made by peeling the rhizomes and washing them thoroughly before they are reduced to pulp; but because of the time, labor and expenses incurred, peeling is not generally done in the Philippines.

The pulp is then washed, strained and put into a tub and the starch separated from the fiber by sieving and squeezing. Several sievings and washings are necessary to get rid of fibers, insects, soil particles and other impurities. The starch settles at the bottom of the tub, and is then taken out to dry. Mats are generally used for drying in the Philippines, the time of drying depending on weather conditions. Quick and thorough drying is necessary to the production of high quality starch. In Laguna, it takes a day for two men to crush enough rhizomes to produce a cavan of starch and another day for the two men

to wash the starch. In Figure 2 is shown the amount of starch that can be obtained from ten hills of arrowroot harvested at the ages of 8, 9, 10, 11, and 12 months. Arrowroot starch keeps well if it is thoroughly dried and stored in sealed containers. The manufacture of arrowroot starch is probably in its highest degree of perfection on the estates in St. Vincent and Bermuda where the greatest cleanliness is observed and where "the various processes of manufacture and drying and packing are done in houses roofed with glass so as to keep away dust and other foreign matter, and thus to insure the making of a product of great purity."—Nicohls, H. A. A Textbook of Tropical Agriculture. 616 pp., New York, 1929.

9. COST OF PRODUCTION

The preparation of land for the planting of arrowroot is practically the same as that for the planting of corn and other unirrigated crops. As no actual figures are available on the cost of producing arrowroot and of preparing arrowroot starch, the following estimates are only approximate:

Cost of preparing land, seed, planting, weeding, and cultivation of one hectare of arrowroot	₱75.00
Cost of harvesting and cleaning rhizomes from one hectare	100.00
Cost of crushing, extracting, cleaning and drying starch from one hectare of rhizomes	250.00
Total	425.00

Placing the production at 2,000 kilograms of arrowroot starch per hectares less one-half of the production obtained in this work, and considering that the price of arrowroot starch is ₱0.45 a kilogram at this writing, the margin of profit in the cultivation of arrowroot including the manufacture of its starch is wide. In Lilio, Laguna, where arrowroot is cultivated in the coconut groves or planted between rows of bananas, 40 meters of arrowroot plants yield on the average one sack of rhizomes; 100 meters therefore, will yield 2.5 sacks and one hectare planted at 1 meter by 1 meter will yield 250 sacks. It is claimed that one sack of starch requires five sacks of rhizomes. Among the flours and starches, the arrowroot starch sells at the highest price and the demand for it is steady.

ILLUSTRATIONS

PLATE I. An arrowroot plant at the age of 11 months and 8 days.
II. Yields of 10 hills of arrowroot at the ages of 8, 9, 10, 11, and 12 months.

PLATE I. An arrowroot plant at the age of 11 months and 8 days

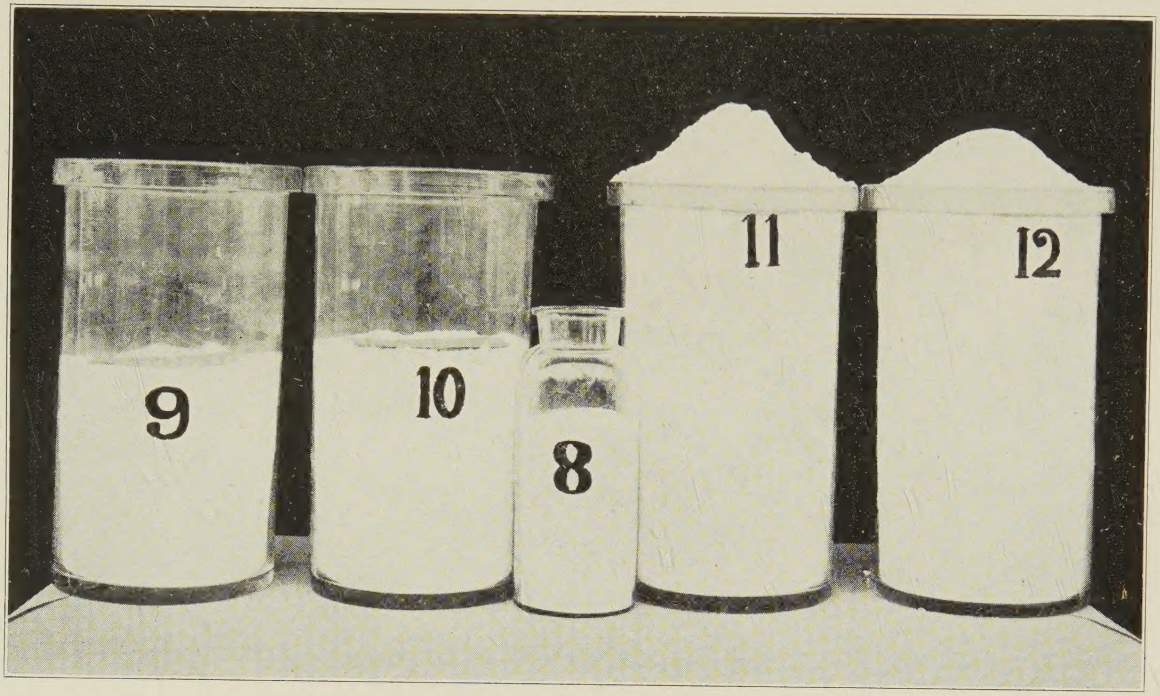

PLATE II. Yields of 10 hills of arrowroot at the ages of 8, 9, 10, 11, and 12 months